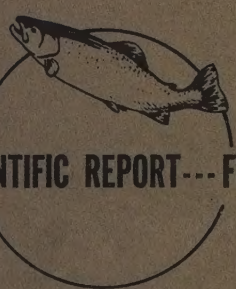
DISPLAY COPY

Catch Rate, Size, Sex, and Food of Tunas and other Pelagic Fishes taken by Trolling off Oahu, Hawaii, 1951-55



SPECIAL SCIENTIFIC REPORT---FISHERIES No. 250

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State, or cooperating Agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, Arnie J. Suomela, Commissioner

CATCH RATE, SIZE, SEX, AND FOOD OF TUNAS AND OTHER PELAGIC FISHES TAKEN BY TROLLING OFF OAHU, HAWAII, 1951-55

By

Albert L. Tester

and

Eugene L. Nakamura
Fishery Research Biologists
Pacific Oceanic Fishery Investigations
Honolulu, Hawaii

Special Scientific Report--Fisheries No. 250

WASHINGTON: December 1957

NOTE: This report is also Contribution No. 96 of the Hawaii Marine Laboratory, University of Hawaii.

ABSTRACT

Catch rate, lure preference, size, weight-length relation, sex and maturity, and food data are presented for the following species of fish: skipjack, little tunny, yellowfin, and dolphin. Where available similar data are reported for frigate mackerel, wahoo, and jack. These fishes were caught by trolling off the northeast coast of Oahu, Hawaii, during the period 1951-55.

The following inferences were made: The highest availability for all species combined occurred from May to October; no lure preference was found; the presence of one to several size groups was indicated by the weight distributions for these fishes; weight-length relations indicated a sexual difference in dolphin but not for the others; sex ratios showed a preponderance of males for skipjack, equal proportion of both sexes for little tunny and yellowfin, and a preponderance of females for dolphin, although considerable diversity of sex ratios between schools was observed for the latter; gonad examinations revealed mature specimens for all species except yellowfin; food of these troll-caught fishes consisted primarily of fishes, cephalopods, and crustaceans; interspecific competition for food was indicated.

CONTENTS

	Page
Methods	1
Catch and catch rate	3
Lure preference	5
Size composition	7
Skipjack	7
Little tunny	9
Yellowfin	11
Dolphin	11
Weight-length relations	14
Sex and maturity	14
Skipjack	14
Little tunny	14
Yellowfin	15
Dolphin	15
Other fish	17
Food	17
Skipjack	17
Little tunny	17
Yellowfin	17
Dolphin	21
Wahoo	21
Frigate mackerel	21
General discussion	21
Summary	24
Literature cited	24

ILLUSTRATIONS

FIGURE Page

Frontispiece: The 46-foot vessel, Salpa, used in catching tuna and other pelagic fishes. The trolling poles are lowered when fishing.

1. Fishing area off the northeast coast of Oahu, Territory of Hawaii. 2

2. Average annual catch per hour's trolling for all species combined and for the four most abundant species in the catch over the period 1951 to 1955. 3

3. Average monthly catch per hour's trolling for all species combined and for the four most abundant species in the catch over the period 1951 to 1955. 5

4. The three main types of lures used in trolling. 6

5. Weight composition of skipjack by months for the combined data of 1951 to 1955. 9

6. Weight composition of little tunny by months for the combined data of 1951 to 1955. . . . 9

7. Weight composition of yellowfin by months for the combined data of 1951 to 1955. 11

8. Weight composition of dolphin by months for the combined data of 1951 to 1955. 11

9. Weight-length relation of dolphin. 15

10. Relative importance of fishes, cephalopods, and crustaceans in the diets of skipjack, little tunny, yellowfin, and dolphin. 21

CATCH RATE, SIZE, SEX, AND FOOD OF TUNAS AND OTHER PELAGIC FISHES TAKEN BY TROLLING OFF OAHU, HAWAII, 1951-55

By

Albert L. Tester

and

Eugene L. Nakamura
Fishery Research Biologists
Pacific Oceanic Fishery Investigations
Honolulu, Hawaii

During 1951 to 1955 inclusive, the 46-foot research vessel Salpa (frontispiece) of the Hawaii Marine Laboratory, University of Hawaii, conducted trolling operations off Kaneohe Bay on the windward or northeast side of Oahu. Fishing was undertaken primarily to stock the ponds of the Coconut Island laboratory with tunas and other pelagic fishes for studies of their response to stimuli. The studies were supported by three annual contracts (June 1951 to May 1954) between the University of Hawaii and the Pacific Oceanic Fishery Investigations.

Incidental to the fishing operations, data were accumulated on the catch rate, size, sex, and food of the several species which were caught. The data are summarized in this report primarily to make them available to other research workers studying the biology of these pelagic species. Such inferences as may be made concerning the life histories of the fish are presented briefly and should be considered tentative in view of the paucity of data in many instances.

The species discussed in this report are referred to by their common English names as follows:

Scientific name	English name
Katsuwonus pelamis	Skipjack
Euthynnus yaito	Little tunny
Neothunnus macropterus	Yellowfin
Auxis thazard	Frigate mackerel
Coryphaena hippurus	Dolphin
Caranx stellatus?	Jack
Acanthocybium solandri	Wahoo

METHODS

Fishing methods used in 1951 have been described by Tester (1952) and, in general, did not change in subsequent years. During 1951 and 1952, ordinarily six cotton trolling lines were used, two (about 90 feet in length) from each of two outrigger poles, and one (about 30 feet) from each side of the stern. During 1953 to 1955, the four outrigger lines were used, but for the most part only one line was trolled from the stern and, on infrequent occasions, even this was omitted. Since the catch rate is calculated as the average catch per hour rather than per line per hour[1/] this introduces a bias in year to year comparisons, but this is considered insufficient to account wholly for the changes in catch rate to be noted later.

Stainless-steel leader wires (about 6 feet in length) were snapped to the ends of the cotton lines. To these were attached a variety of lures. Trolling was conducted at a speed of about 6 knots, which kept the lures on or near the surface. After capture, viable fish were retained in the ship's livewell.

Fishing was confined mostly to the morning hours, with the ship leaving the dock at the Coconut Island laboratory between 0700 and 0800 hours and returning between 1200 and 1300 hours. On clearing Kaneohe Bay we would usually bear towards Mokumanu Island (fig. 1) and then head out to sea, the course being governed by such bird flocks as were sighted within the area of fishing. Often the ship would circle under a working bird flock for several minutes. Whenever strikes were made, trolling would be continued in the vicinity until there was reasonable assurance that no further catches could be made. Occasionally trolling would be terminated, even though more fish could have been caught in the vicinity, in order to avoid delay in transporting viable fish to the ponds at Coconut Island. The general fishing area, shown in figure 1, was

[1/] Accurate data on number of lines used per trip are not available in some years.

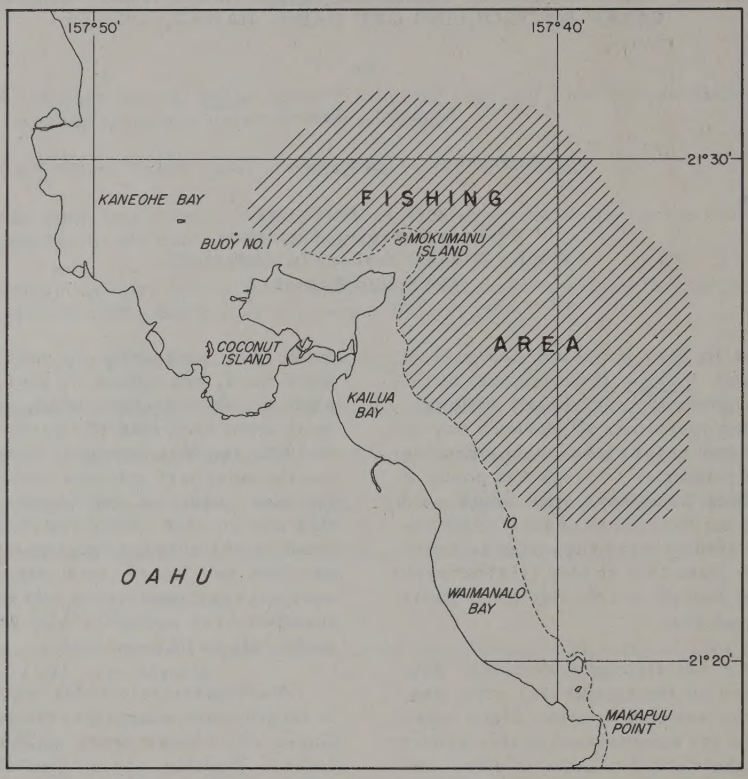


Figure 1.--Fishing area off the northeast coast of Oahu, Territory of Hawaii.

about 4 miles wide and 10 miles long. Only rarely was there fishing outside of this area.

In July and August 1953, 148 skipjack were caught by pole-and-line fishing, using nehu (Stolephorus purpureus) as live bait. These fish were not included in the analysis of troll catch rate, although they were used in certain other analyses in this report.

Fishing was done mostly during the summer months, but some effort was expended in other months of the year. The fishing periods for each year were as follows:

Year	Months of fishing
1951	January to October
1952	June to August; October
1953	June to August
1954	June to December
1955	January; May; July to September

At the laboratory the following determinations were made on the non-viable fish:

length--distance in centimeters from the tip of the closed jaws to the fork of the tail as determined on a measuring board (Hiatt and Hamre 1945)

weight--measured to the nearest one-fourth pound on a dial-type spring scale with weighing pan

sex and maturity--from examination of gonads, with gonad stage indicated by 1, immature; 2, maturing; 3, nearly mature; 4, ripe; and 5, spent

food--stomach contents were removed and preserved in jars containing 10-percent formalin; later, the total amount of food was determined volumetrically, the organisms were identified to the most convenient

exclusive category and their percentage by volume of the total was estimated. The number of each type of food item was also recorded. In cases where the fish had gorged itself on a large number of small organisms the number was recorded as "numerous."

For those species which were brought back alive and released into the pond, mostly little tunny and yellowfin, the only sampling data available is an estimate of the weight of each fish. As the estimates are considered reasonably accurate, they are included in the analysis of the weight composition of the catch.

CATCH AND CATCH RATE

Data on the catch according to year, month, and species are included in table 1. In the following discussion our results will be compared with those of Welsh (1949b), who conducted trolling operations in the waters between Hawaii and Kauai, including the present fishing area, from March 1948 to December 1948 and from February 1949 to June 1949. He used both the Salpa and the Territorial Division of Fish and Game's research vessel with fishing methods essentially similar to ours.

Table 1 shows that most of our catch (96 percent) was comprised of four species: skipjack, little tunny, dolphin, and yellowfin. Frigate mackerel, wahoo, and jack made up the remainder. The following tabulation of percentages shows that the same four species formed the bulk of the catch during the earlier period (Welsh 1949b), but that little tunny were of much greater relative abundance:

Species	1951-55	1948-49 (Welsh 1949b)
Skipjack	32.7	8.4
Little tunny	23.7	63.9
Dolphin	23.0	18.4
Yellowfin	16.8	4.2
Frigate mackerel	2.6	-
Wahoo	1.0	3.7
Jack	0.2	1.5

Annual variation in catch rate for all species combined and for each of the four principal species is shown in figure 2. The comparison between years is subject to error because of the variation in number of lines used and because of the variable seasonal coverage.

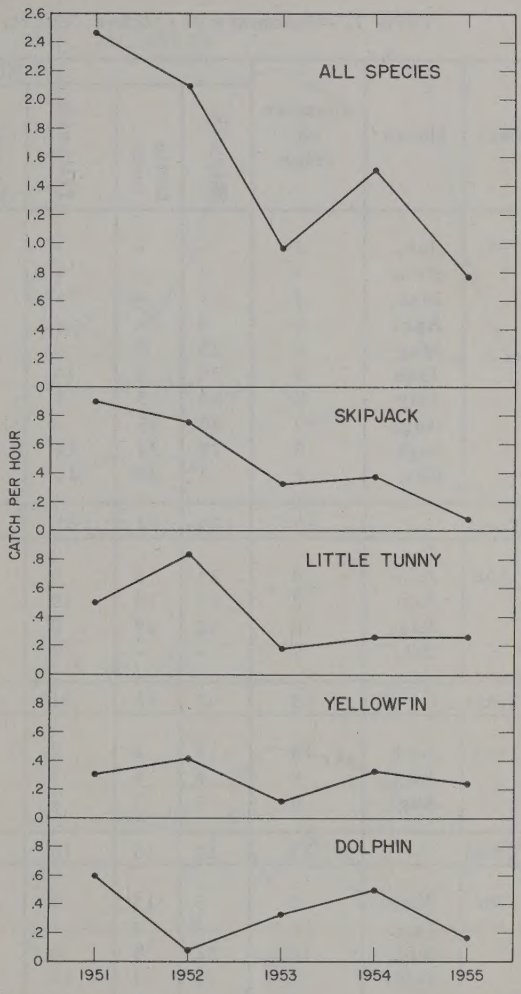


Figure 2.--Average annual catch per hour's trolling for all species combined and for the four most abundant species in the catch over the period 1951 to 1955.

The apparent availability of fish to trolling declined from a high of 2.46 fish per hour in 1951 to 0.97 in 1953, increased to 1.51 in 1954 and then decreased sharply to 0.77 in 1955. The apparent general decline following 1951 persists when the analysis is confined to comparable data for the summer months. The general trend can be attributed chiefly to a decreasing availability of skipjack over the entire period and a low availability of little tunny from 1953 to 1955. These apparent changes, however, may well be

Table 1.--Summary of catches, effort, and catch rate by species, month, and year

Year	Month	Number of trips	Number caught								Number of trolling hours	Mean catch per hour
			Skipjack	Little tunny	Yellowfin	Frigate mackerel	Dolphin	Wahoo	Jack	Total		
1951	Jan.	2	-	-	-	-	-	-	-	-	3.75	0.00
	Feb.	3	2	-	-	-	1	-	-	3	6.50	0.46
	Mar.	3	1	-	-	-	1	-	-	2	7.50	0.27
	Apr.	4	3	-	-	-	6	1	-	10	13.75	0.73
	May	8	23	5	-	1	24	-	1	54	21.50	2.51
	June	9	38	9	14	12	13	-	-	86	22.75	3.78
	July	8	24	3	4	1	16	-	-	48	20.25	2.37
	Aug.	9	38	15	3	4	23	-	-	83	24.75	3.35
	Sept.	8	19	21	14	4	2	1	-	61	21.75	2.80
	Oct.	6	2	30	16	-	13	-	1	62	23.75	2.61
Total		60	150	83	51	22	99	2	2	409	166.25	2.46
1952	June	10	21	8	6	-	5	-	-	40	23.50	1.70
	July	12	29	29	19	-	-	2	-	79	33.50	2.36
	Aug.	10	12	29	8	-	1	-	-	50	21.25	2.35
	Oct.	1	-	-	1	-	-	-	-	1	3.00	0.33
Total		33	62	66	34	-	6	2	-	170	81.25	2.09
1953	June	13	18	8	7	-	10	-	-	43	32.50	1.32
	July	9	4	4	3	-	16	-	-	27	29.25	0.92
	Aug.	5	5	3	-	-	1	-	-	9	19.75	0.46
Total		27	27	15	10	-	27	-	-	79	81.50	0.97
1954	June	7	5	13	-	-	7	-	-	25	17.50	1.43
	July	6	3	3	1	-	41	-	-	48	17.00	2.82
	Aug.	10	21	5	8	-	10	3	-	47	29.50	1.59
	Sept.	7	11	1	10	-	4	1	-	27	17.50	1.54
	Oct.	8	6	5	18	1	2	-	-	32	24.00	1.33
	Nov.	7	2	6	5	-	-	-	-	13	20.25	0.64
	Dec.	1	-	-	-	-	-	-	-	-	1.50	0.00
Total		46	48	33	42	1	64	4	-	192	127.25	1.51
1955	Jan.	1	1	-	-	-	-	-	-	1	3.00	0.33
	May	3	-	2	1	-	1	-	-	4	9.25	0.43
	July	4	-	3	-	-	3	-	-	6	9.25	0.65
	Aug.	8	3	6	2	-	3	1	-	15	23.75	0.63
	Sept.	3	-	3	10	-	2	-	-	15	8.25	1.82
Total		19	4	14	13	-	9	1	-	41	53.50	0.77

local, i.e., confined to the area of fishing. This is suggested for skipjack, at least, by comparing our trolling results with those of the commercial pole-and-line fishery. Instead of a downward trend over the period 1951 to 1953, in the commercial fishery both 1951 and 1953 were years of high availability whereas 1952 was a year of low availability (Yamashita, In press). The comparison is vitiated in part by differences in size composition of the catches; the troll-caught fish were mostly small, whereas the commercially caught fish were a mixture of small and large sizes.

The average monthly availability of troll-catchable fish for the combined data of the years 1951 to 1955 is shown in figure 3. Although fish were caught in all months of the year except December (when effort was low), the highest availability occurred from May to October. Skipjack and dolphin were taken throughout most of the year but with a peaking of availability during the summer months. The commercial skipjack catch also peaks during the summer months (Yamashita, In press). No little tunny were taken during January to April, but this cannot be regarded as significant in view of the small number of hours trolled during this period. Welsh (1949b) reported good catches of this species during March, April, and May, 1948 and during February and April 1949. The peaking of the availability of yellowfin during September and/or October seems to be a common occurrence, for it was encountered during each of the three years (1951, 1954, and 1955) in which fishing was done during these months.

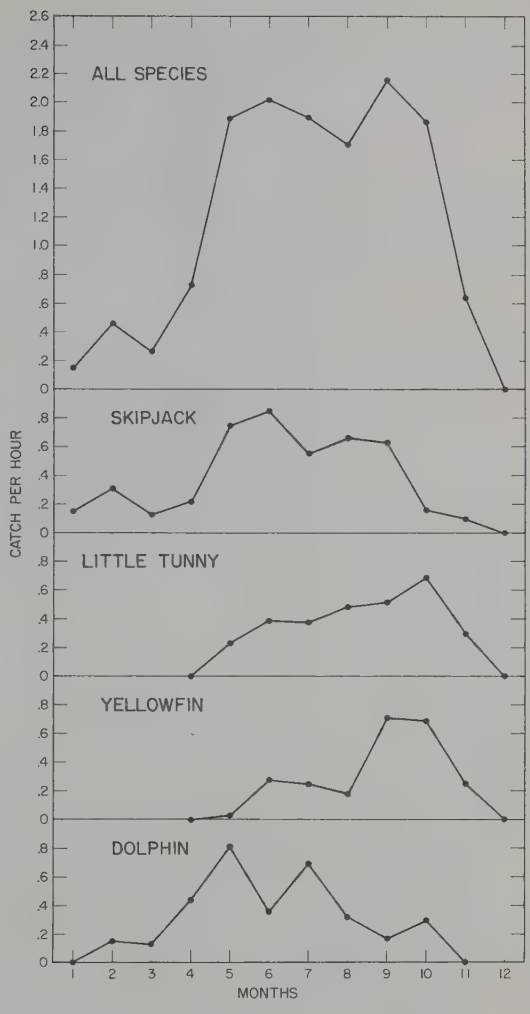


Figure 3.--Average monthly catch per hour's trolling for all species combined and for the four most abundant species in the catch over the period 1951 to 1955.

LURE PREFERENCE

During 1951 and 1953 records were kept of the strikes and catches on the several lures which were used. The lures, as shown in figure 4, were of three general types: (1) "metal squid" with a heavy blue, silver, or red metal body and white rubber arms, (2) "feather" with a heavy white or red metal head or a hollow silver head to which feathers of variegated color are attached, and (3) "rubber squid," with brown pliable rubber body and arms. Other types used to a small extent included a "plastic squid" and a "rubber fish."

Data on catch rate for all species of fish are shown in table 2.[2/] By comparing the strikes per lure per hour with the catch per lure per hour, it is at once apparent that about the same proportion of fish was lost from each lure during hauling of the line. Of the 3 lures used most extensively in 1951, the brown rubber squid produced the highest catch rate (0.61 fish per lure per hour), the metal squid with red body the second highest (0.42), followed by the feather lure with white head (0.29). The same order persisted when the data were selected to include only days in which the three lures were used simultaneously, with the following catch rates: 0.66, 0.44, and 0.30. However, in 1953

[2/] The fish catch for 1953 does not agree with that of table 1 because lure data were not available for a few days of that year.

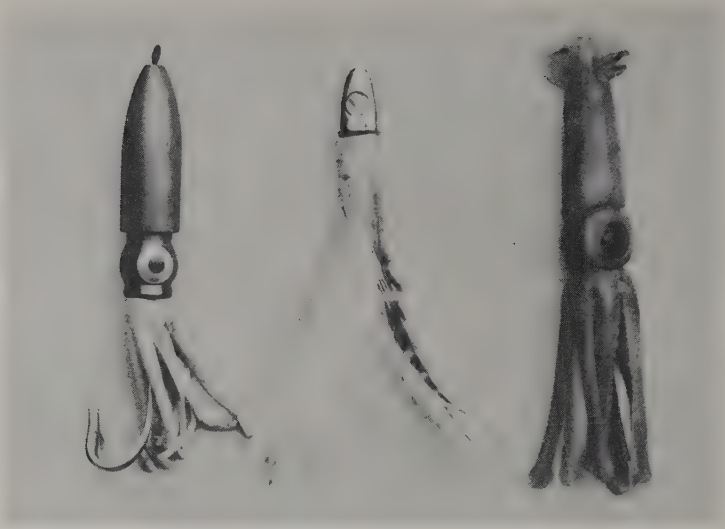


Figure 4.--The three main types of lures used in trolling.

Table 2.--Catch rate for the several lures used in 1951 and 1953

Year	Lure	Hours trolled	Number of strikes	Number of fish caught	Strikes per lure per hour	Catch per lure per hour
1951	Feather: white head	105-1/2	41	31	0.39	0.29
	Feather: red head	13	8	8	0.62	0.62
	Feather: hollow head	43-3/4	25	18	0.57	0.41
	Metal squid: blue body and white rubber arms - "A"	40-3/4	22	19	0.54	0.47
	Metal squid: silver body and white rubber arms - "B"	50-1/4	27	19	0.54	0.38
	Metal squid: red body and white rubber arms - "D"	288	148	121	0.51	0.42
	Metal squid: - "L"	29-1/2	12	8	0.41	0.27
	Metal squid: - "Y"	5-1/4	1	-	0.19	-
	Rubber squid: brown body and arms - "S"	283	213	174	0.75	0.61
	Plastic squid: transparent body and arms - "Z"	33	8	7	0.24	0.21
	Rubber fish: green	9-3/4	4	4	0.41	0.41
1953	Feather: white head	36-1/4	17	13	0.47	0.36
	Metal squid: blue body and white rubber arms - "A"	2-1/2	1	1	0.44	0.44
	Metal squid: red body and white rubber arms - "D"	61-1/4	22	17	0.36	0.28
	Metal squid: "Lai" (Scomberoides sp.) skin skirt	20-1/2	1	1	0.05	0.05
	Rubber squid: brown body and arms - "S"	95-1/2	42	33	0.44	0.35

neither the gross nor the selected data showed the same order. Ranged as above, i.e., brown rubber squid, metal squid with red body, and feather lure, the catch rates were as follows: 0.35, 0.28, and 0.36 for gross data (table 2) and 0.26, 0.18, and 0.26 for selected data. There is no clear evidence that one lure was more attractive than another with respect to form. Similarly there is no significant indication that red lures were more attractive than those of other color, as suggested by Welsh (1949b).

The number of fish caught according to species and lure is shown in table 3 for the four more important species and the three most used lures. In the 1951 data there is the suggestion of a differential attraction; for example, the rubber squid seemed to catch relatively more yellowfin than the other lures. However, the interaction chi-square for the 4 x 3 contingency table is not significant. Moreover, the rather meager 1953 data give no hint of lure preference. Apparently all three lures were about equally attractive to all four species.

SIZE COMPOSITION

The weight distributions of troll-caught skipjack, little tunny, yellowfin, and dolphin are given respectively in tables 4 to 7 and will be discussed below. Formulae for the conversion of weight to length will be given in a later section.

The weight distribution of the remainder of the catch is dismissed with the following notations: 23 frigate mackerel averaged 1-1/2 pounds and ranged from 1 to 2-1/2 pounds; 9 wahoo averaged 26 pounds and ranged from 20 to 33-1/2 pounds; 2 jacks weighed 4 and 8 pounds.

Skipjack

During the 5-year period 288 skipjack (excluding pole-and-line-caught fish) were measured. They averaged 4.9 pounds (47.5 cm.) and ranged from 2 to 17 pounds (30 to 70 cm.) (table 4).

From the monthly weight frequency histograms shown in figure 5 for the combined data of all years, it is evident that the majority of the fish ranged from 3 to 6 pounds with a pronounced mode at 4 pounds. Modal groups of similar size (varying from 44 to 50 cm., i.e., 3-1/2 to 6 pounds) were noted in the commercial catch by Brock (1954), and were considered most likely to be 1-year-olds, i.e., fish near the end of their first or the beginning of their second year of life. As Brock's data indicate that spawning extends over a 7-month period (February to September), a considerable size range of the "1-year-olds" would be expected. Presumably the majority of the troll-caught fish may be placed in this age category.

In figure 5 there is no apparent progression of the modal groups from month to month. This indicates that as the fish grow larger, they no longer frequent the inshore habitat that was fished. That they occur offshore is shown by modal groups ranging from 3-1/2 to 29 pounds (44 to 81 cm.) in samples from the commercial fishery examined by Brock (1954).

Table 3.--Number of fish of the more important species taken by each of the three most used lures

Year	Lure	Skipjack	Little tunny	Yellowfin	Dolphin	Total
1951	Feather: white head	12	10	3	5	30
	Metal squid: red body and white arms	34	31	9	34	108
	Rubber squid: brown body and arms	63	37	28	38	166
	Total	109	78	40	77	304
1953	Feather: white head	4	2	2	5	13
	Metal squid: red body and white arms	5	4	3	5	17
	Rubber squid: brown body and arms	11	6	5	11	33
	Total	20	12	10	21	63

Table 4.--Size frequency of troll-caught skipjack (1951-55)

Year	Month	Pounds																	Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1951	Feb.	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	2
	Mar.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
	Apr.	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	2
	May	-	-	-	10	3	7	1	1	-	-	-	-	-	-	-	-	-	22
	June	-	-	4	12	10	7	2	1	1	-	1	-	-	-	-	-	-	38
	July	-	-	5	6	6	3	2	1	1	-	-	-	-	-	-	-	-	24
	Aug.	-	-	1	19	10	5	2	-	1	-	-	-	-	-	-	-	-	38
	Sept.	-	-	2	13	1	3	-	-	-	-	-	-	-	-	-	-	-	19
	Oct.	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	2
Total		-	-	12	60	32	29	7	4	3	-	1	-	-	-	-	-	-	148
1952	June	-	-	1	10	6	3	-	-	-	-	-	1	-	-	-	-	-	21
	July	-	-	1	17	4	4	2	-	-	-	-	-	-	-	-	-	-	29
	Aug.	-	-	2	8	1	3	-	-	-	-	-	-	-	-	-	-	-	12
Total		-	-	3	35	11	10	2	-	-	-	-	1	-	-	-	-	-	62
1953	June	-	-	7	10	1	-	-	-	-	-	-	-	-	-	-	-	-	18
	July	-	-	1	-	1	2	-	-	-	-	-	-	-	-	-	-	-	4
	Aug.	-	-	2	1	2	-	-	-	-	-	-	-	-	-	-	-	-	5
Total		-	-	10	11	4	2	-	-	-	-	-	-	-	-	-	-	-	27
1954	June	-	-	-	-	4	-	-	1	-	-	-	-	-	-	-	-	-	5
	July	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	3
	Aug.	-	-	2	5	-	7	3	2	-	2	-	-	-	-	-	-	-	21
	Sept.	-	-	-	4	3	1	-	1	1	1	-	-	-	-	-	-	-	11
	Oct.	-	1	2	2	-	-	1	-	-	-	-	-	-	-	-	-	-	6
	Nov.	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Total		-	3	4	13	8	8	4	4	1	3	-	-	-	-	-	-	-	48
1955	Jan.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
	Aug.	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Total		-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	3

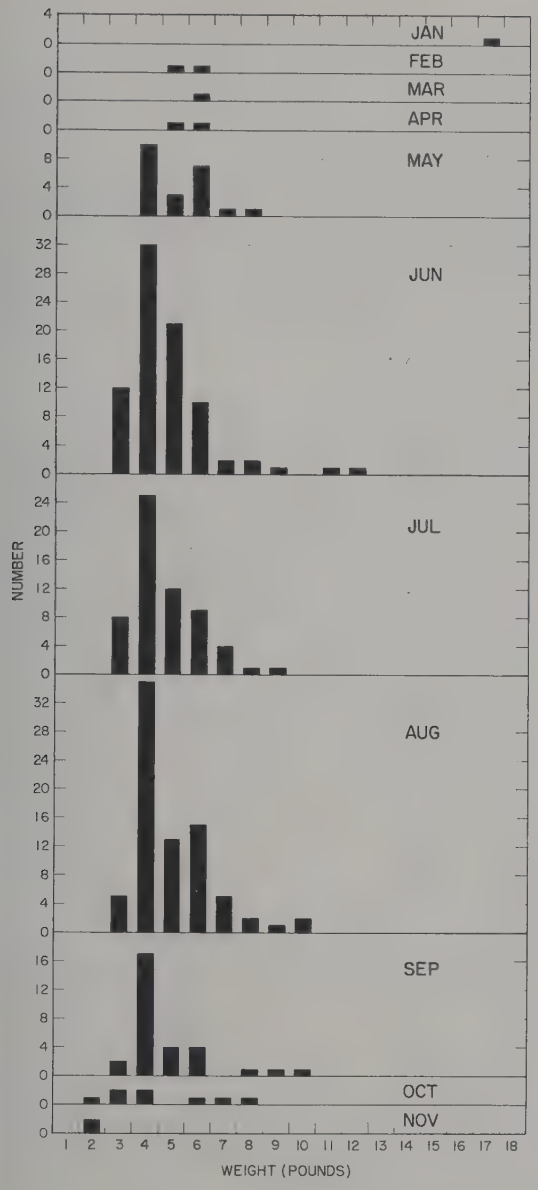


Figure 5.--Weight composition of skipjack by months for the combined data of 1951 to 1955.

Little Tunny

Measurements were made of 208 little tunny, which averaged 4.8 pounds (48 cm.) and ranged from about 1 to 15 pounds (30 to 70 cm.).

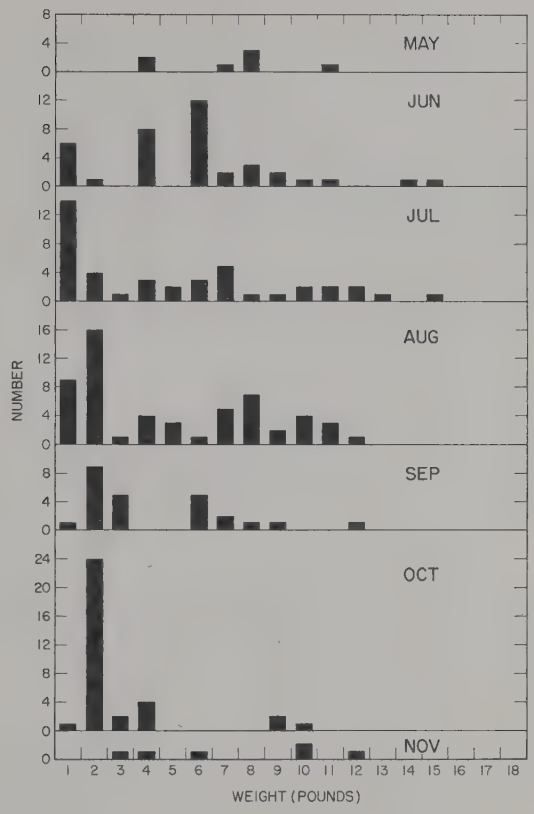


Figure 6.--Weight composition of little tunny by months for the combined data of 1951 to 1955.

The weight composition by months for the combined data of all years, shown in figure 6, suggests a slight progression of modes initially located at 1 and 6 pounds in June. However, the progression may be an artifact caused by combining variable annual data, for it is not indicated in the data for individual years (table 5). Rather, these data show a strong influx of 2-pound (36 cm.) fish during August, September, and October, 1951, and of 1-pound fish (30 cm.) during June, July, and August, 1952. There are relatively small numbers of 1- and 2-pound fish in other years. Fish of 6 to 8 pounds (50 to 57 cm.) seem to form a second modal group in 1951, 1954, and 1955, whereas a third modal group at 10 to 11 pounds (60 to 63 cm.) may be present in 1952. Thus the presence of at least two and possibly three age groups is indicated. Further discussion is not warranted because of the paucity of the present data.

Table 5.--Size frequency of troll-caught little tunny (1951-55)

Year	Month	Pounds																	Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1951	May	-	-	-	2	-	-	-	3	-	-	-	-	-	-	-	-	-	-	5
	June	-	-	-	-	-	6	1	1	-	-	-	-	-	-	1	-	-	-	9
	July	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	3
	Aug.	-	4	-	-	-	1	4	4	-	-	-	-	-	-	-	-	-	-	13
	Sept.	1	8	4	-	-	3	2	1	1	-	-	1	-	-	-	-	-	-	21
	Oct.	1	22	2	2	-	-	-	-	1	1	-	-	-	-	-	-	-	-	29
Total		2	34	6	4	-	10	10	9	2	1	-	1	-	-	1	-	-	-	80
1952	June	3	1	-	1	-	-	-	-	-	1	1	-	-	1	-	-	-	-	8
	July	13	3	1	2	-	2	-	1	-	2	2	2	1	-	-	-	-	-	29
	Aug.	9	11	-	2	3	-	-	-	-	2	1	1	-	-	-	-	-	-	29
Total		25	15	1	5	3	2	-	1	-	5	4	3	1	1	-	-	-	-	66
1953	June	2	-	-	4	-	2	-	-	-	-	-	-	-	-	-	-	-	-	8
	July	1	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	4
	Aug.	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Total		3	1	1	6	2	2	-	-	-	-	-	-	-	-	-	-	-	-	15
1954	June	1	-	-	3	-	4	1	2	2	-	-	-	-	-	-	-	-	-	13
	July	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	3
	Aug.	-	-	-	-	-	-	-	1	1	1	2	-	-	-	-	-	-	-	5
	Sept.	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
	Oct.	-	2	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	5
	Nov.	-	-	1	1	-	1	-	-	-	2	-	1	-	-	-	-	-	-	6
Total		1	2	1	6	-	7	3	3	4	3	2	1	-	-	-	-	-	-	33
1955	May	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	2
	July	-	1	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	3
	Aug.	-	-	-	1	-	-	1	2	1	1	-	-	-	-	-	-	-	-	6
	Sept.	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3
Total		-	2	1	1	-	1	2	2	2	1	1	-	-	-	1	-	-	-	14

Yellowfin

Measurements were made on 147 yellowfin, which averaged 6.5 pounds (54 cm.) and ranged from 1 to 18 pounds (29 to 72 cm.) (table 6).

The monthly data shown in figure 7 indicate the progression of a mode starting at about 5 or 6 pounds in June and advancing to about 10 pounds in November. This apparent growth agrees well with that observed for a yellowfin held in captivity, which increased in weight from about 5 pounds when it started feeding on July 2, 1951, to 11 pounds when it died on January 13, 1952 (Tester 1952).

Based on a study of the ovaries, June (1953) concludes that yellowfin in Hawaiian waters spawn from the middle of May to the end of October. Moore (1951), from a study of the weight composition of the commercial pole-and-line and longline catches, concludes that yellowfin attain an average weight of about 7 pounds (54 cm.) by the end of their first year and an average weight of 46 pounds (103 cm.) by the end of their second year of life. Our data agree well with Moore's estimate of the weight at the end of the first year, i.e., the mean weight of our troll-caught fish is 6.8 pounds during August, assuming this month to be the middle of the spawning period. However, fish which average 7 pounds in August and 10 pounds in November would have to grow very rapidly during the winter, spring, and early summer to attain a mean weight of 46 pounds during the following August. It may be that our estimate of 10 pounds in November is biased by selective sampling, i.e., the fish may tend to move out of the area as they get larger, although the advancing mode noted above seems to indicate the contrary.

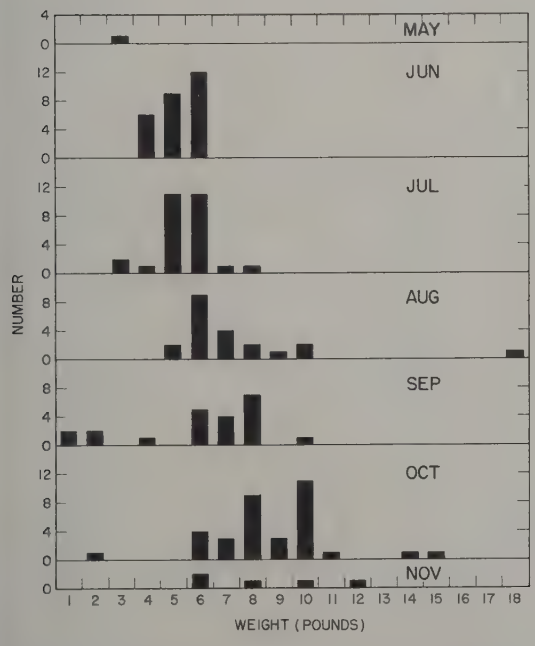


Figure 7.--Weight composition of yellowfin by months for the combined data of 1951 to 1955.

Dolphin

Measurements were made on 198 dolphin which averaged 6.8 pounds (72 cm.) and ranged from 1-1/2 to 37 pounds (41 to 121 cm.) (table 7).

From the monthly weight distribution, shown in figure 8, there is some indication of bimodality

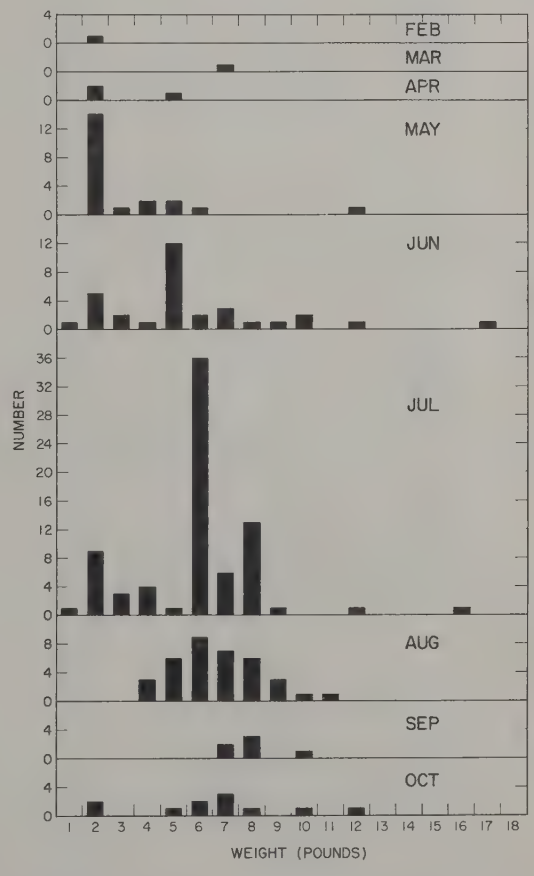


Figure 8.--Weight composition of dolphin by months for the combined data of 1951 to 1955.

Table 6.--Size frequency of troll-caught yellowfin (1951-55)

Year	Month	Pounds																	Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1951	June	-	-	-	-	9	5	-	-	-	-	-	-	-	-	-	-	-	-	14
	July	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	4
	Aug.	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	3
	Sept.	2	2	-	-	-	2	2	6	-	-	-	-	-	-	-	-	-	-	14
	Oct.	-	1	-	-	-	2	-	6	1	5	-	-	-	-	-	-	-	-	15
Total		2	3	2	-	9	13	3	12	1	5	-	-	-	-	-	-	-	-	50
1952	June	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
	July	-	-	-	1	10	8	-	-	-	-	-	-	-	-	-	-	-	-	19
	Aug.	-	-	-	-	2	3	1	-	-	2	-	-	-	-	-	-	-	-	8
	Oct.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Total		-	-	-	7	12	11	1	-	-	3	-	-	-	-	-	-	-	-	34
1953	June	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	7
	July	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	3
Total		-	-	-	-	1	7	1	1	-	-	-	-	-	-	-	-	-	-	10
1954	July	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
	Aug.	-	-	-	-	-	2	2	2	1	-	-	-	-	-	-	-	-	1	8
	Sept.	-	-	-	1	-	3	2	1	-	1	-	-	-	-	-	-	-	-	8
	Oct.	-	-	-	-	-	2	3	3	2	5	1	-	-	1	1	-	-	-	18
	Nov.	-	-	-	-	-	2	-	1	-	1	-	1	-	-	-	-	-	-	5
Total		-	-	-	1	-	10	7	7	3	7	1	1	-	1	1	-	-	1	40
1955	May	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Aug.	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2
	Sept.	-	-	-	-	-	4	4	-	-	-	2	-	-	-	-	-	-	-	10
Total		-	-	1	-	-	6	4	-	-	-	2	-	-	-	-	-	-	-	13

Table 7.--Size frequency of troll-caught dolphin (1951-55)

Year	Month	Pounds																																				Total
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	
1951	Feb.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Mar.	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	Apr.	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
	May	-	14	1	2	2	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	23
	June	-	-	-	1	10	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
	July	-	1	-	1	1	6	1	5	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
	Aug.	-	-	-	-	4	5	5	5	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
	Sept.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	2
	Oct.	-	-	-	-	1	2	3	1	-	1	-	1	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
Total		-	18	1	4	19	14	12	11	1	2	-	3	-	-	-	-	-	-	-	1	1	1	-	1	-	1	-	-	1	-	-	1	-	-	-	-	-	92
1952	June	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	5
	Aug.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Total		-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	6
1953	June	1	1	2	-	2	2	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
	July	-	3	3	3	-	5	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
	Aug.	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Total		1	4	5	3	2	7	1	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27
1954	June	-	4	-	-	-	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
	July	1	5	-	-	-	23	5	6	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41
	Aug.	-	-	-	2	1	4	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
	Sept.	-	-	-	-	-	-	-	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
	Oct.	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Total		1	11	-	2	1	27	7	10	2	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64
1955	May	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	July	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
	Aug.	-	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
	Sept.	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Total		-	-	-	1	1	2	2	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9

in fish less than 10 pounds in weight, with one mode at 2 pounds (46 cm.) and a second ranging from 5 to 8 pounds (64 to 76 cm.). Only a few specimens larger than 10 pounds were taken over the period.

WEIGHT-LENGTH RELATIONS

Weight-length relations were calculated for each of the four most abundant species according to the usual formula relating weight, W (in pounds), with length, L (in centimeters):

$$W = aL^b$$

$$\log W = \log a + b \log L$$

The constants log a and b as determined by least squares are given in table 8, along with other pertinent data. Although the numbers of fish are small, the calculations are included because samples of small fish are usually unavailable from commercial catches.

With the dolphin, unlike the tunas, there was an indication of sexual dimorphism in the weight-length relation. Beyond 6 pounds (68 cm.) the males tended to be heavier for a given length than the females (fig. 9). This is probably related to a well-known sexual dimorphism in the shape of the head, the males having a much higher forehead than the females (Schuck 1951).

SEX AND MATURITY

Summary data on sex and gonad maturity of six species of fish are given in table 9. The numbers of fish do not agree with those of previous tables as many of the fish, particularly little tunny, yellowfin, and dolphin, were transferred alive to holding ponds and consequently were not examined in respect to sex or stage of maturity.

Skipjack

Of 347 troll- and pole-and-line-caught skipjack, 3 had gonads so undeveloped that the sex could not be determined. The remainder comprised 61.0 percent males and 39.0 percent females. The departure from a 1:1 ratio was statistically significant as determined by the chi-square test.

Brock (1954) points out that, in his samples from the commercial catch, males were significantly more abundant than females in the fall of the year (September to December) but not in spring (March to May) nor in the summer (June to August). When our data are arranged according to season (table 10) there is a significant preponderance of males in the summer. At present we can offer no satisfactory explanation of these differences in sex ratio.

Of the 344 fish which could be sexed, 12 were recorded as "immature" (gonad stage 1) and 4 were "spent" (stage 5). Some of the fish recorded as "immature" may have been spent, for they ranged in weight from 3 to 17 pounds. The four fish classed as "spent" ranged from 5 to 7 pounds. Despite the apparent confusion in separating these two stages, it is evident (table 9) that the majority of the fish were "maturing" or "nearly mature" and that a few may have spawned. Considering their size and assumed age, it seems safe to conclude with Brock that skipjack may mature in 1 year.

Little Tunny

It was impossible to determine the sex of 8 small (1 to 2 pounds) little tunny. Of the remaining 93 fish, males were slightly but not significantly less numerous than females, forming 48.4 percent of the catch.

The gonads of most of the fish were in the "maturing" condition (stages 2 and 3). The 7

Table 8.--Number of fish, size range, and constants in the weight-length relations (log W = log a + b log L) for four species of troll-caught fish

Species	Number of fish	Size range (pounds)	Log a	b
Skipjack	268	2-1/2 to 12-1/2	-4.7262	3.2164
Little tunny	101	1 to 15	-4.6229	3.1544
Yellowfin	59	1 to 17-3/4	-4.2015	2.9045
Dolphin	133	1-1/2 to 12	-4.1966	2.7111

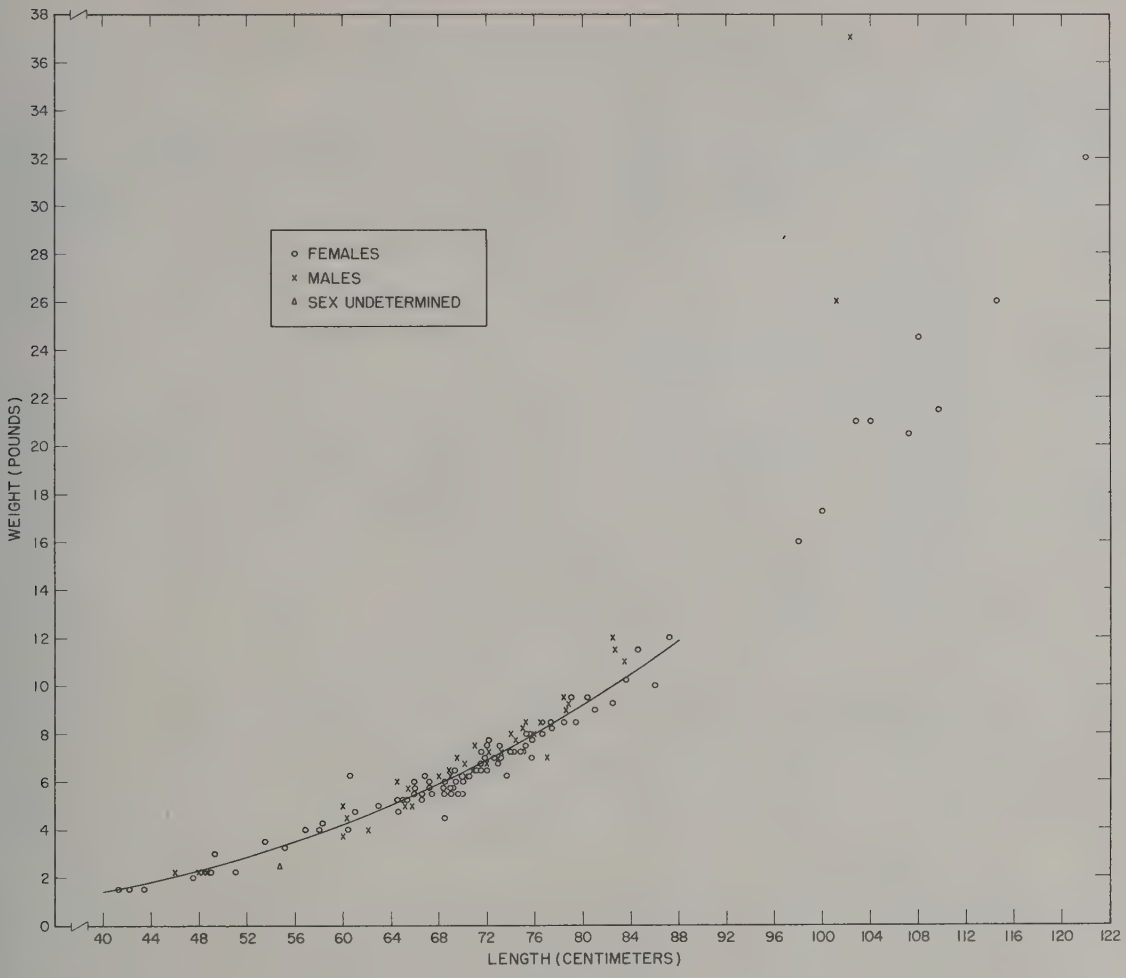


Figure 9.--Weight-length relation of dolphin.

fish classed as "spent" (stage 5) comprised 2 fish of about 5 pounds and 5 fish of 10 to 11 pounds.

Yellowfin

In contrast to skipjack and little tunny, most of the yellowfin were judged to be immature. Of the 59 fish examined for sex, 14 had gonads so immature that the sex could not be ascertained. The remainder were mostly "immature" (stage 1) with a few "maturing" (stage 2). In view of the size of these fish and their presumed age, it would seem doubtful that yellowfin mature by the end of their first year.

Of the yellowfin which could be sexed, males were in the minority (45 percent), although the ratio did not deviate significantly from 1:1. This is in agreement with the sex ratio of the smaller (less than 80 to 90 pounds) fish taken by longline near the Equator, but it is in contrast to the sex ratio for the larger longline-caught fish both near the Equator and in Hawaiian waters, in which males strongly predominate (Iverson 1956). The reason for the change in sex ratio is obscure.

Dolphin

The dolphin showed a significant deviation from the 1:1 ratio, with males (28.5 percent) much less numerous than females (71.5 percent). All males were either "immature" (stage 1) or in early stages of maturing (stage 2). The females included stages ranging from "immature" to "mature" (stage 4). The fish classed as "immature" ranged from 1-1/2 to 8-1/2 pounds. Of the 12 fish classed as "mature" (but not "running ripe")

Table 9.--Sex and maturity stage of the various species

Species	Sex	Maturity stage					
		1 (immature)	2 (maturing)	3 (nearly mature)	4 (ripe)	5 (spent)	All
Skipjack	Males	6	43	158	2	1	210
	Females	6	18	97	10	3	134
	Undetermined	-	-	-	-	-	(3)
	Total	12	61	255	12	4	344
Little tunny	Males	3	13	24	1	4	45
	Females	11	12	17	5	3	48
	Undetermined	-	-	-	-	-	(8)
	Total	14	25	41	6	7	93
Yellowfin	Males	18	2	-	-	-	20
	Females	19	6	-	-	-	25
	Undetermined	-	-	-	-	-	(14)
	Total	37	8	-	-	-	45
Dolphin	Males	18	24	-	-	-	42
	Females	36	20	37	12	-	105
	Total	54	44	37	12	-	147
Frigate mackerel	Males	1	3	2	1	-	7
	Females	-	4	6	-	-	10
	Total	1	7	8	1	-	17
Wahoo	Males	-	5	-	-	-	5
	Females	-	1	1	1	-	3
	Total	-	6	1	1	-	8

Table 10.--Number of male and female skipjack taken during four periods of the year and the probability that the sex ratio is not significantly different from 1 : 1 as determined by a chi-square test

Sex	December-February	March-May	June-August	September-November	Total
Male	0	12	174	24	210
Female	3	13	105	13	134
Both	3	25	279	37	344
Probability		>0.05	<0.01	>0.05	<0.01

7 ranged from 5 to 8 pounds and 5 ranged from 10 to 32 pounds.

There is considerable diversity in the proportion of males and females between schools. For example, 11 females and 6 males were caught from a school of 5- to 9-pound fish on August 8, 1951. In contrast, of 31 fish taken from a school of 5- to 9-pound fish on July 12, 1954, 29 were females and only 2 were males.

Other Fish

We have few data on frigate mackerel and wahoo. It might be noted, however, that the 17 frigate mackerel, which were all about 1-1/2 pounds in weight, were mostly at stages 2 and 3, but included one male (2-1/2 pounds) classed as "mature." The 8 wahoo, which ranged from 20 to 33 pounds, were mostly at stage 2, but the largest specimen, a female, was classed as "mature."

FOOD

The results of the stomach analyses for skipjack, little tunny, yellowfin, and dolphin are presented in tables 11, 12, 13, and 14, respectively. The numbers of stomachs examined were as follows: 67 skipjack, 32 little tunny, 15 yellowfin, 52 dolphin, 3 wahoo, and 2 frigate mackerel. The stomach collections were made in 1951, 1952, and 1953.

The advantages and disadvantages of the various methods of evaluating food components have been discussed by Reintjes and King (1953). They conclude "....that those food items that rank large in number, large in volume, and high in frequency of occurrence are important foods—at the time and in the area sampled." Data for all three of these methods of analysis have been incorporated into the above-mentioned tables.

In identifying the ingested fishes, the following references proved to be helpful: Brock (1950), Jordan and Evermann (1905), and Smith (1949). The scientific names of the food fishes referred to in this report are for the most part in accordance with Brock (1950). Identification of the invertebrates was aided by reference to Berry (1914), Edmondson (1946), Hiatt (no date), and Townsley (1950).

We wish to thank Drs. A. H. Banner and D. W. Strasburg for their help in the identification of various organisms found in the stomachs.

The food of these troll-caught fishes is composed almost entirely of fishes, cephalopods, and crustaceans. This is in agreement with the results of other investigators who have noted the stomach contents of these same pelagic species in Hawaii and elsewhere (Imamura 1949, Nakamura 1949, Reintjes and King 1953, Ronquillo 1953, Shapiro 1948, Welsh 1949a, and others). A discussion of the food of each species follows.

Skipjack

For skipjack ranging in size from 40.0 to 61.1 cm. the most important food item by volume appeared to be cephalopods (squid), with fishes second in importance (table 11). Not only did squid comprise the largest volume, but the numbers found were also high, lending further support to their importance. This is in contrast to results which were obtained by Welsh (1949a) from samples collected in waters adjacent to Oahu but not confined to the area delineated in figure 1. In 21 stomachs he found fishes to be the most important food by volume. In our samples fishes did have the highest frequency of occurrence.

Of the crustaceans the stomatopod larvae comprised the largest volume and highest occurrence. Some of the skipjack were found to be gorged with stomatopods. Some were also found to be gorged with crab megalops.

Little Tunny

The results for the little tunny ranging in size from 31.2 to 66.8 cm. show that fishes comprised the greatest volume of food with crustaceans next in rank (table 12). The 196 samples examined by Welsh (1949a) for this same species showed just the opposite.

Gorging on stomatopods and crab megalops was also observed for the little tunny.

Yellowfin

In the food of yellowfin ranging in size from 47.4 to 58.9 cm., squid provided the greatest bulk (table 13). Welsh (1949a) also found that squid were important as food for yellowfin around the island of Oahu. Reintjes and King (1953) found that cephalopods were relatively unimportant in the food of yellowfin caught at the surface near land in the region of the Line and Phoenix islands.

The presence of seahorses (Syngnathidae) in the stomach contents of yellowfin in Hawaiian waters has been previously reported by Herald (1949). As seen in table 13, seahorses were

Table 11.--Stomach contents of 67 troll-caught skipjack (number of stomachs: 49 in 1951, 10 in 1952, 8 in 1953)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.^{3}	Percent	Number	Percent	
Fishes					
Exocoetidae					
Parexocoetus brachypterus	0.7	---*	1	1.5	1
Sphyraenidae					
Sphyraena helleri	6.0	0.2	1	1.5	1
Serranidae					
Unidentified sp.	13.3	0.5	2	3.0	14
Bramidae					
Collybus drachme	166.2	6.3	7	10.4	33
Carangidae					
Unidentified sp.	264.0	10.0	10	14.9	18
Chaetodontidae					
Unidentified sp.	2.3	---*	1	1.5	4
Acanthuridae					
Unidentified sp.	7.1	0.3	2	3.0	3
Unidentified fish remains	225.5	8.6	32	47.8	88
Total fishes	685.1	26.0			
Cephalopoda					
Decapoda					
Ommastrephidae					
Ommastrephes hawaiiensis	810.6	30.8	13	19.4	41
Unidentified sp.	594.9	22.6	12	17.9	33
Sepiolidae					
Heteroteuthis hawaiiensis	247.4	9.4	4	6.0	Numerous
Unidentified squid	116.0	4.4	11	16.4	22
Total decapod cephalopods	1768.9	67.2			
Crustacea					
Stomatopoda					
Unidentified larvae	161.4	6.1	25	37.3	Numerous
Decapoda					
Unidentified shrimp	0.1	---*	1	1.5	7
Unidentified anomuran	0.1	---*	1	1.5	1
Brachyuran megalopa	15.1	0.6	20	30.0	Numerous
Total crustaceans	176.7	6.7			
Grand total	2630.7				

* Less than 0.1 percent.

Table 12.--Stomach contents of 32 troll-caught little tunny (number of stomachs: 20 in 1951, 11 in 1952, 1 in 1953)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.^{3}	Percent	Number	Percent	
Fishes					
Syngnathidae					
Hippocampus sp.	1.0	---*	2	6.2	2
Serranidae					
Unidentified sp.	516.3	28.3	8	25.0	Numerous
Priacanthidae					
Priacanthus cruentatus	26.2	1.4	1	3.1	1
Unidentified sp.	121.2	6.6	1	3.1	8
Bramidae					
Collybus drachme	30.3	1.7	1	3.1	1
Carangidae					
Decapturus sp.	308.0	16.9	2	6.2	Numerous
Unidentified sp.	151.2	8.3	3	9.4	6
Ostraciidae					
Lactoria diaphanus	2.3	0.1	3	9.4	6
Pegasidae					
Pegasus papilio	0.4	---*	1	3.1	1
Unidentified fish remains	518.1	28.4	20	62.5	Numerous
Total fishes	1675.0	91.8			
Cephalopoda					
Decapoda					
Unidentified squid	1.3	---*	1	3.1	1
Total decapod cephalopods	1.3	---*			
Crustacea					
Stomatopoda					
Unidentified larvae	28.4	1.6	7	21.9	Numerous
Decapoda					
Unidentified caridean shrimp	101.0	5.5	2	6.2	Numerous
Penaeidae					
Unidentified sp.	1.0	---*	1	3.1	1
Unidentified reptantian larvae	1.8	---*	1	3.1	4
Brachyuran megalopa	16.6	0.9	5	15.6	Numerous
Total crustaceans	148.8	8.2			
Grand total	1825.1				

* Less than 0.1 percent.

Table 13.--Stomach contents of 15 troll-caught yellowfin (number of stomachs: 10 in 1951, 4 in 1952, 1 in 1953)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	$cm.^3$	Percent	Number	Percent	
Fishes					
Syngnathidae					
Hippocampus histrix	11.3	1.6	3	20.0	10
Hippocampus sp.	29.4	4.2	5	33.3	Numerous
Bramidae					
Unidentified sp.	86.5	12.4	1	6.7	5
Blennidae					
Runula sp.	0.4	---*	1	6.7	1
Dactylopteridae					
Dactyloptena orientalis	2.3	0.3	1	6.7	1
Balistidae					
Balistapus sp.	3.5	0.5	1	6.7	1
Monacanthidae					
Unidentified sp.	4.6	0.7	1	6.7	1
Ostraciidae					
Lactoria diaphanus	9.6	1.4	3	20.0	10
Lactoria sp.	0.4	---*	1	6.7	1
Tetrodontidae					
Arothron sp.	0.2	---*	1	6.7	1
Pegasidae					
Pegasus papilio	10.9	1.6	4	26.7	14
Unidentified fish remains	40.5	5.8	9	60.0	Numerous
Total fishes	199.6	28.6			
Cephalopoda					
Decapoda					
Ommastrephidae					
Ommastrephes hawaiiensis	380.1	54.4	4	26.7	9
Unidentified squid	48.8	7.0	6	40.0	Numerous
Total decapod cephalopods	428.9	61.4			
Crustacea					
Stomatopoda					
Unidentified larvae	59.7	8.6	15	100.0	Numerous
Euphausiacea					
Euphausidae					
Unidentified sp.	0.4	---*	1	6.7	1
Decapoda					
Unidentified caridean shrimp	1.0	0.1	1	6.7	3
Palinuridae					
Panulirus japonicus	1.0	0.1	1	6.7	1
Brachyuran megalopa	7.6	1.1	6	40.0	26
Total crustaceans	69.7	10.0			
Grand total	698.2				

* Less than 0.1 percent.

the most common identifiable group of the food fishes utilized by the yellowfin in our samples.

Dolphin

An examination of the stomachs of 52 dolphin ranging in size from 41.3 to 121.0 cm. showed the importance of fish in their diet (table 14). Cephalopods and crustaceans together comprised less than 3 percent of the total volume. Flyingfishes (Exocoetidae) appeared to be particularly significant both in volume and occurrence. Welsh's study of 58 stomach samples showed almost identical results. Flyingfish have also been reported in the food of dolphin caught in North Carolina waters (Schuck 1951).

Cymothoid isopods were found in two stomachs. Members of this family are known to be parasitic on fish. It is possible that they were parasitic on the food fishes and thus incidentally ingested. One of the stomachs containing cymothoid isopods also contained a monacanthid, an exocoetid, and unidentified fish remains. The other contained exocoetids and a syngnathid in addition to the isopod.

A further item of interest was the presence of a coral rock about 1/2 $cm.^3$ in volume in one of the stomachs. The rock may have been ingested accidentally while feeding on reef-dwelling forms. Other contents of this stomach were penaeid shrimps, stomatopod larvae, a crab megalopa, remains of a fish, and remains of a squid.

Wahoo

All three of the stomachs examined contained remains of fish. One of the food fishes was identified as a carangid. The sizes of these three wahoo were 104.1, 111.1, and ca. 123 cm.

Frigate Mackerel

Of the two frigate mackerel stomachs examined, one contained numerous crab megalops and stomatopod larvae, while the other contained 8 crab megalops, numerous stomatopod larvae, 2 anomuran larvae, and a small octopus. The frigate mackerel were 33.2 and 36.6 cm. in length.

General Discussion

The relative importance by volume of the three major food categories for the skipjack, little tunny, yellowfin, and dolphin is portrayed in figure 10. The little tunny and dolphin appear to rely heavily upon fishes for food, while the skipjack and yellowfin have a more varied diet utilizing all three of the major food groups.

The similarity between the diets of skipjack and yellowfin and between little tunny and dolphin suggests the likelihood of interspecific competition. Evidence of competition for food between skipjack and yellowfin was furnished on several occasions when the Salpa would catch both species while trolling under a working bird flock. The occurrence of the same invertebrate organisms in the stomachs of both skipjack and yellowfin seems to attest the presence of competition, but the absence of food fish species common to both fails to support it (tables 11 and 13). Evidence for competition between the little tunny and the dolphin may be seen in the number of food fish species common to both (tables 12 and 14). The fishes most prevalent in the food of the dolphin, however, were the flyingfishes

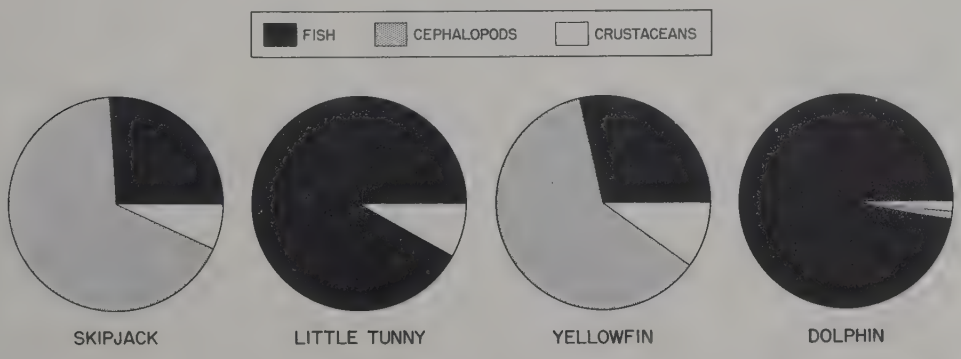


Figure 10.--Relative importance of fishes, cephalopods, and crustaceans in the diets of skipjack, little tunny, yellowfin, and dolphin.

Table 14.--Stomach contents of 52 troll-caught dolphin (number of stomachs: 53 in 1951, 5 in 1952, 14 in 1953)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.^{3}	Percent	Number	Percent	
Fishes					
Clupeidae					
Spratelloides delicatulus	3.4	---*	4	7.7	6
Synodontidae					
Synodus variegatus	0.5	---*	1	1.9	1
Belonidae					
Ablennes hians	121.0	3.4	1	1.9	1
Hemiramphidae					
Hemiramphus brasiliensis	239.2	6.7	2	3.8	2
Euleptorhamphus viridis	40.5	1.1	1	1.9	1
Exocoetidae					
Parexocoetus brachypterus	402.9	11.3	3	5.8	11
Exocoetus volitans	4.9	0.1	1	1.9	4
Cypselurus sp.	429.6	12.0	3	5.8	4
Unidentified sp.	605.8	17.0	16	30.8	Numerous
Syngnathidae					
Hippocampus histrix	8.3	0.2	4	7.7	7
Hippocampus sp.	9.0	0.3	4	7.7	8
Holocentridae					
Holocentrus sp.	3.5	---*	1	1.9	1
Serranidae					
Unidentified sp.	1.6	---*	1	1.9	1
Coryphaenidae					
Coryphaena hippurus	7.8	0.2	2	3.8	2
Mullidae					
Unidentified sp.	61.0	1.7	2	3.8	3
Carangidae					
Decapturus pinnulatus	14.4	0.4	1	1.9	1
Caranx melampygus	14.4	0.4	1	1.9	2
Unidentified sp.	32.3	0.9	2	3.8	2
Kyphosidae					
Kyphosus sp.	23.5	0.7	1	1.9	1
Chaetodontidae					
Chaetodon sp.	1.6	---*	1	1.9	4
Unidentified sp.	0.5	---*	1	1.9	1
Blenniidae					
Runula sp.	2.4	---*	4	7.7	5
Zanclidae					
Zanclus canescens	30.8	0.9	1	1.9	1
Istiophoridae					
Istiophorus orientalis	17.4	0.5	1	1.9	1
Scorpaenidae					
Taenianotus triacanthus	2.4	---*	1	1.9	1
Unidentified sp.	4.6	0.1	1	1.9	3
Scombridae					
Unidentified sp.	765.0	21.4	2	3.8	2

* Less than 0.1 percent.

Table 14.--Stomach contents of 52 troll-caught dolphin (number of stomachs: 53 in 1951, 5 in 1952, 14 in 1953) (cont'd)

Food organisms	Total volume		Stomachs in which occurred		Number of organisms
	cm.^{3}	Percent	Number	Percent	
Monacanthidae					
Cantherines pardalis	10.1	0.3	2	3.8	2
Cantherines sp.	5.4	0.2	1	1.9	1
Unidentified sp.	30.4	0.9	3	5.8	4
Ostraciidae					
Lactoria diaphanus	20.5	0.6	11	21.2	18
Ostracion lentiginosum	11.3	0.3	3	5.8	3
Tetrodontidae					
Unidentified sp.	30.7	0.9	2	3.8	2
Diodontidae					
Diodon holacanthus	46.1	1.3	3	5.8	8
Pegasidae					
Pegasus papilio	1.1	---*	1	1.9	1
Unidentified fish remains	470.2	13.2	25	48.1	Numerous
Total fishes	3474.1	97.3			
Cephalopoda					
Decapoda					
Unidentified squid	40.1	1.1	4	7.7	6
Total decapod cephalopods	40.1	1.1			
Crustacea					
Isopoda					
Cymothoidae					
Unidentified sp.	3.5	---*	2	3.8	3
Stomatopoda					
Unidentified larvae	45.3	1.3	16	30.8	Numerous
Decapoda					
Penaeidae					
Unidentified sp.	5.1	0.1	5	9.6	24
Brachyuran megalopa	4.0	0.1	6	11.5	12
Total crustaceans	57.9	1.6			
Grand total	3572.1				

* Less than 0.1 percent.

(Exocoetidae), which were not found in the stomachs of the little tunny. In view of the lack of specificity in the diets, it is probable that if all four species were present in the same area at the same time, they would vie with each other for whatever food was available.

Reliance upon inshore fauna was evident in the stomach contents of all four species, but this is not surprising since all of our catches were made relatively close to land. The pelagic larval and juvenile stages of many of the food fishes were those of species which spend their adult stages among the reefs or waters close to the reefs. This holds true for some of the invertebrates also. Undoubtedly the reefs of Kaneohe Bay and adjacent areas play an important role in contributing food to the area sampled. However, the extent of this contribution is presently unknown.

SUMMARY

1. Catch, catch rate, lure preference, size frequencies, weight-length relations, sex and maturity, and food are reported for tunas and other pelagic fishes caught by trolling off Kaneohe Bay, Oahu. Trolling operations were conducted aboard the University of Hawaii's research vessel Salpa during 1951 through 1955.

2. The bulk of the catch was composed of skipjack, dolphin, little tunny, and yellowfin. The highest availability for all species combined occurred in the months of May to October. Yellowfin availability was consistently high during September and October.

3. Among the various types of lures used, no preference was found with respect to form or color of the lure.

4. Weight distribution of skipjack showed no progression of modes, indicating migration away from the fishing area as the fish grew larger. The majority of the skipjack were presumed to be "1-year-olds." Weight distribution of little tunny appeared to indicate the presence of two and possibly three age groups. Weight distribution of yellowfin indicated growth from 5 or 6 pounds in June to 10 pounds in November. Weight distribution of dolphin appeared to indicate bimodality in fish less than 10 pounds.

5. Weight-length relations were calculated for skipjack, little tunny, yellowfin, and dolphin. Beyond 68 cm. male dolphin tended to be heavier than females at a given length.

6. The sex ratio of skipjack showed a preponderance of males. Gonad examinations indicate that skipjack may mature in 1 year. The sex ratio of little tunny showed approximately an equal proportion of males and females. Gonad examinations showed the majority of little tunny in the "maturing" stages, with a few mature and spent fish. The sex ratio for yellowfin was similar to that of the little tunny. Gonad examinations revealed no mature yellowfin. The sex ratio of dolphin showed a preponderance of females, although there was considerable diversity in the sex ratio between schools. Gonad examinations revealed the presence of mature females but no mature males.

7. Food analyses showed that the diet of these pelagic fishes comprised primarily fishes, cephalopods, and crustaceans. Some evidence of interspecific competition for food was indicated. Reliance upon inshore fauna was evident in the stomach contents of all the species examined.

LITERATURE CITED

BERRY, S. S.
1914. The cephalopoda of the Hawaiian Islands. U. S. Bur. Fish., Bull. 32 (for 1912): 255-362.

BROCK, V. E.
1950. Keys to Hawaiian Fishes. Hawaii (Terr.) Div. Fish and Game, Spec. Bull. No. 4, 191 p.

1954. Some aspects of the biology of the aku, Katsuwonus pelamis, in the Hawaiian Islands. Pacific Science 8(1): 94-104.

EDMONDSON, C. H.
1946. Reef and shore fauna of Hawaii. Bernice P. Bishop Mus., Spec. Publ. 22, 381 p.

HERALD, E. S.
1949. Pipefishes and seahorses as food for tuna. California Fish and Game 35(4): 329.

HIATT, R. W.
Laboratory and field syllabus in taxonomy of marine invertebrates. Mimeographed, Univ. of Hawaii, undated.

HIATT, R. W., and C. J. HAMRE
1945. A device for measuring fish. Jour. Wildlife Management 9(1): 79-81.

IMAMURA, Y.
1949. The Japanese skipjack fishery. (From Suisan Kōza, the Text of the Fishery, Vol. 6, Fishing Section, pp. 17-94. Published by Dai Nippon Suisan Kai, Tokyo, March 5, 1949.) U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fish. No. 49, 67 p. (Translated from the Japanese language by W. G. Van Campen.)

IVERSEN, E. S.
1956. Size variation of central and western Pacific yellowfin tuna. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fish. No. 174, 23 p.

JORDAN, D. S., and B. W. EVERMANN
1905. The aquatic resources of the Hawaiian Islands. Part I. The shore fishes of the Hawaiian Islands, with a general account of the fish fauna. U. S. Fish Comm., Bull. 23 (for 1903), Part 1, 574 p., 73 plates.

JUNE, F. C.
1953. Spawning of yellowfin tuna in Hawaiian waters. U. S. Fish and Wildlife Service, Fish. Bull. 54(77): 47-64.

MOORE, H. L.
1951. Estimation of age and growth of yellowfin tuna (Neothunnus macropterus) in Hawaiian waters by size frequencies. U. S. Fish and Wildlife Service, Fish. Bull. 52(65): 133-149.

NAKAMURA, H.
1949. The tunas and their fisheries. (Published by Takeuchi Shobō; Tokyo, 1949.) U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fish. No. 82, 115 p. (Translated from the Japanese language by W. G. Van Campen.)

REINTJES, J. W., and J. E. KING
1953. Food of yellowfin tuna in the Central Pacific. U. S. Fish and Wildlife Service, Fish. Bull. 54(81): 91-110.

RONQUILLO, I. A.
1953. Food habits of tunas and dolphins based upon the examination of their stomach contents. Philipp. Jour. Fish. 2(1): 71-83.

SHAPIRO, S.
1948. The Japanese tuna fisheries. SCAP Nat. Resour. Sect. Rept. No. 104: 60 p. (Reproduced in 1948 as U. S. Fish and Wildlife Service, Fish. Leaflet 297.)

SCHUCK, H. A.
1951. Notes on the dolphin (Coryphaena hippurus) in North Carolina waters. Copeia 1951(1): 35-39.

SMITH, J. L. B.
1949. The sea fishes of South Africa: South Africa. Central News Agency, Ltd., 550 p.

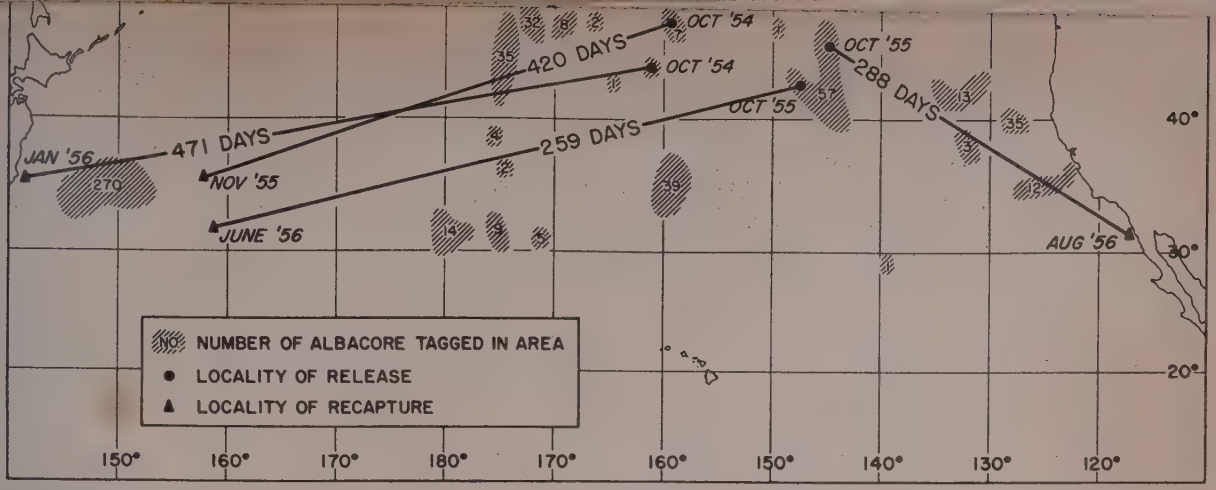
TESTER, A. L.
1952. Establishing tuna and other pelagic fishes in ponds and tanks. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fish. No. 71, 20 p.

TOWNSLEY, S. J.
1950. Adult and larval stomatopod crustaceans occurring in Hawaiian waters. M. S. Thesis. Dept. of Zool., Univ. of Hawaii, 95 p.

WELSH, J. P.
1949a. A preliminary study of food and feeding habits of Hawaiian kawakawa, mahimahi, ono, aku, and ahi. Hawaii (Terr.) Div. Fish and Game, Fish. Prog. Rept. I, No. 2, 26 p. (in Fish and Game, Spec. Bull. No. 2, 1950).

1949b. A trolling survey of Hawaiian waters. Hawaii (Terr.) Div. Fish and Game, Fish. Prog. Rept. I, No. 4, 30 p. (in Fish and Game, Spec. Bull. No. 2, 1950).

YAMASHITA, D. T.
In press. Analysis of the catch statistics of the Hawaiian skipjack fishery. U. S. Fish and Wildlife Service, Fish. Bull.



Albacore tagging locations of the Pacific Oceanic Fishery Investigations studies, showing numbers of fish tagged, recovery points and number of days between tagging and recapture.

TAGGING ALBACORE

On a Japanese Bait Boat

By
W. G. Van Campen and Garth I. Murphy

● During the past 2 or 3 years several Albacore tagged by American researchers off the California coast or in the mid-Pacific north of Hawaii have been recaptured by Japanese fishing boats operating east of the Japanese islands. These tag recoveries have given valuable hints as to the migration pattern of this important species in the North Pacific, and American agencies are continuing such tagging on a considerable scale. It has been generally felt by the people engaged in this program that tagging tuna on the American side of the ocean alone could at best give only half the picture of *Albacore* migration, so it was for the purpose of interesting the Japanese in carrying on a similar tagging program on their western Pacific fishing grounds that the project described below was undertaken.

After preliminary arrangements had been made from Honolulu, the authors traveled to Japan in May, 1956. Through the Research Section of the Japanese Fisheries Agency, we were put in touch with Director Ichiro Nomoto of the Mie Prefecture Fisheries Experiment Station, who agreed to let us attempt to tag pole-and-line-caught Albacore aboard the Prefecture's "fisheries guidance vessel" *Jini Maru*. Two cruises were made between May 28 and June 21, and 270 Albacore were tagged with the California Type G plastic "spaghetti" tag.

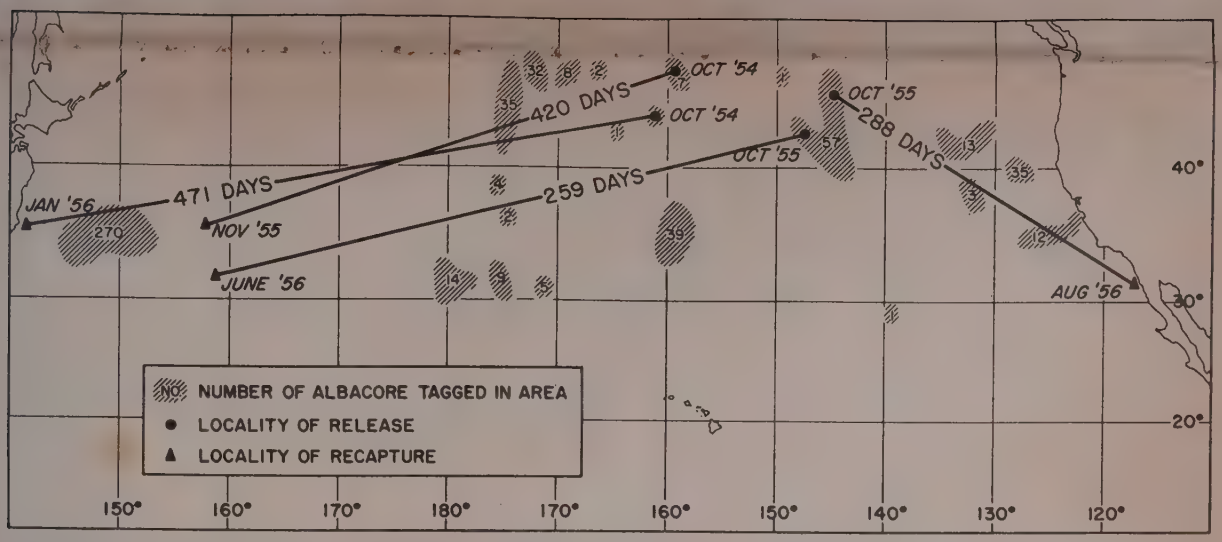
We boarded the *Jini Maru* at Shimizu, a port in Shizuoka Prefecture about 100 miles southwest of Tokyo, after a brief conference at which the ship's officers heard and approved the proposed tagging plans. The ship had come in the day before from an unsuccessful Skipjack fishing trip off southern Japan and was to sail that evening, and perhaps the desire of all hands to make the best use of their brief shore leave had something to do with the celerity with which agreement was reached and the conference brought to a successful close.

Fisheries guidance ships like the *Jini Maru* are operated by all of the prefectures of Japan which have any sizeable commercial tuna fleet, and by some which have not. Detailed reports of all of their operations are published, but their primary function is making money for the prefecture's general fund. The main assurances that we were called upon to give were that the tagging would be done in such a way as not to interfere with the business of catching tuna, and that all Albacore thrown over the side would be paid for at or above the going market price.

Mr. Van Campen and Mr. Murphy are members of the staff of the Pacific Oceanic Fishery Investigations, where the former is Japanese translator and Mr. Murphy is assistant director.

Boat and Bait

● The ship sailed from Shimizu about 7 o'clock in the evening, and with an overnight run to the baiting ground ahead of us, we addressed ourselves to the challenging task of settling comfortably into our assigned quarters. The *Jini Maru*, a very typical example of a class of live-bait boats built in Japan after the war, is 106 feet long, 196.5 tons gross, and carries, during the pole-and-line season, a crew of 55 men. We were given one broad plank bunk in a room already occupied by the two young observers regularly assigned to the ship and were allowed to divide any space we



Albacore tagging locations of the Pacific Oceanic Fishery Investigations studies, showing numbers of fish tagged, recovery points and number of days between tagging and recapture.

TAGGING ALBACORE

On a Japanese Bait Boat

● During the past 2 or 3 years several Albacore tagged by American researchers off the California coast or in the mid-Pacific north of Hawaii have been recaptured by Japanese fishing boats operating east of the Japanese islands. These tag recoveries have given valuable hints as to the migration pattern of this important species in the North Pacific, and American agencies are continuing such tagging on a considerable scale. It has been generally felt by the people engaged in this program that tagging tuna on the American side of the ocean alone could at best give only half the picture of *Albacore* migration, so it was for the purpose of interesting the Japanese in carrying on a similar tagging program on their western Pacific fishing grounds that the project described below was undertaken.

After preliminary arrangements had been made from Honolulu, the authors traveled to Japan in May, 1956. Through the Research Section of the Japanese Fisheries Agency, we were put in touch with Director Ichiro Nomoto of the Mie Prefecture Fisheries Experiment Station, who agreed to let us attempt to tag pole-and-line-caught

By
W. G. Van Campen and
Garth I. Murphy

Albacore aboard the Prefecture's "fisheries guidance vessel" *Jini Maru*. Two cruises were made between May 28 and June 21, and 270 Albacore were tagged with the California Type G plastic "spaghetti" tag.

We boarded the *Jini Maru* at Shimizu, a port in Shizuoka Prefecture about 100 miles southwest of Tokyo, after a brief conference at which the ship's officers heard and approved the proposed tagging plans. The ship had come in the day before from an unsuccessful Skipjack fishing trip off southern Japan and was to sail that evening, and perhaps the desire of all hands to make the best use of their brief shore leave had something to do with the celerity with which agreement was reached and the conference brought to a successful close.

Fisheries guidance ships like the *Jini Maru* are operated by all of the prefectures of Japan which have any sizeable commercial tuna fleet, and by some which have not. Detailed reports of all of their operations are published, but their primary function is making money for the prefecture's general fund. The main assurances that we were called upon to give were that the tagging would be done in such a way as not to interfere with the business of catching tuna, and that all Albacore thrown over the side would be paid for at or above the going market price.

Mr. Van Campen and Mr. Murphy are members of the staff of the Pacific Oceanic Fishery Investigations, where the former is Japanese translator and Mr. Murphy is assistant director.

Boat and Bait

● The ship sailed from Shimizu about 7 o'clock in the evening, and with an overnight run to the baiting ground ahead of us, we addressed ourselves to the challenging task of settling comfortably into our assigned quarters. The *Jini Maru*, a very typical example of a class of live-bait boats built in Japan after the war, is 106 feet long, 196.5 tons gross, and carries, during the pole-and-line season, a crew of 55 men. We were given one broad plank bunk in a room already occupied by the two young observers regularly assigned to the ship and were allowed to divide any space we

could find to suit our convenience. We soon found that there was not enough room between the bulkheads to stretch out out in nor enough space overhead to sit up on the bunk. The nearby galley was a narrow cubby-hole, almost filled by a large range with two great pots set in its top, and presided over by two cheerful, hard-working refugees from intermediate school. All meals were eaten on deck, there being no other practicable space in which to serve them.

Having been built when materials and money were scarce, the *Jini Maru* is, even by Japanese standards, a crudely finished boat, but she has all the essentials of stability, seaworthiness, and reliability needed for her work. Built of steel, with the long overhanging bow typical of Japanese live-bait boats, she gets 9 knots out of a 5-cylinder, 430-hp. diesel, carries up to 400 buckets of bait in her 4 bait wells, and can load about 100 tons of fish. She carries 40 tons of block ice which is crushed with hand tools as needed to cool the ice water in which the catch is held. There is a 15-hp. ammonia sytsem with coils in all fish and ice holds; it is used on longlining cruises to slow down ice loss.

Like commercial boats of her type, the *Jini Maru* livebait fishes for Skipjack from April to September, beginning the season sometimes as far south as Formosa and ending up off northeastern Japan as far north as 45°N. In May and June three to five trips are made with Albacore as the main objective, but even then Skipjack are fished whenever found. After the Skipjack season about half the crew (the older men) leave the ship, longlines and a linehauler are put aboard, and the winter is spent in tuna longlining in Indonesian waters to the tropical Pacific. During the live-bait Skipjack and Albacore season catches are usually landed at major fishing ports such as Shimizu or Yaizu, where canneries, freezers, and Skipjack drying plants are concentrated, and the catches from longlining trips are often sold at the port of Misaki, near the great fresh-fish markets of the Tokyo metropolitan area. As the live-bait fishery moves northward during the summer, the vessel shifts its base and baiting grounds up the coast to locations convenient to the current fishing grounds.

An overnight run from Shimizu up the coast brought the *Jini Maru* off the baiting ground of Hota on the western shore of Tokyo Bay at dawn. Here between 15 and 20 bait-holders, called *kowari*, were anchored offshore in such depths that a tuna boat could come alongside them. These holding nets are suspended from demountable octagonal frames of timber, about 16 feet in diameter, and hold up to 200 buckets of bait.

Live sardines being transferred from a bait-holding net to the bait wells. The fish are bought in "buckets" as the unit of measurement.

The bait dealer soon came out from shore, accompanied by one of three buyers exclusively occupied with traveling about Japan arranging the purchase of bait for this boat. The *Jini Maru* was laid alongside a *kowari*, a crowder was passed through the net to concentrate the bait at the ship's side, and the bait was transferred to the wells bucket-brigade style. In all 318 buckets of 4- to 6-inch sardines were taken aboard from 3 *kowari* in less than an hour. The contents of one bucket were estimated at about 15 pounds of fish, and the price paid was 1,000 yen ($2.75) per bucket. The price varies from about $2.00 to $6.50, depending on the scarcity of bait, and it was said that the contents of a bucket tend to lighten up considerably in periods of scarcity.

Scouting Process

● At about 300 miles offshore, on 35°N. latitude, when the ship reached potential albacore waters, the regular routine of pole-and-line tuna fishing set in. All hands crawled out of their bunks about 4:00 a.m., donned their heavy black-rubber working gear, and took a quick breakfast of *miso* soup and rice. Right after breakfast ready supplies of bait were put in the three small live-boxes located forward, amidships, and aft on the port side, and lookouts were posted, five on the foremast and two on the main. The oldest of the older fishermen took up station on the stern handy to the two trolling lines; the rest of the senior contingent crowded the flying bridge, where a pair of 25X binoculars was mounted; the first-class younger fisherman took up wet but proud positions at their fishing station on the bowsprit; the three baitmen, who were very old indeed, stood by their bait boxes, and the green hands assigned to amidships fishing positions made themselves comfortable on the boat-deck and contributed very little to the operation which the Japanese call *tekisui* or "searching for suitable water." The two observers were on the bridge, dipping up samples of sea water for temperature measurements at least every 15 minutes. Thus manned, the *Jini Maru* worked eastward with so many pairs of eyes scanning the ocean that there seemed little chance for a stray sardine, let alone a tuna school, to escape our vigilance.

Meanwhile in the radio shack the operator searched the air for intelligence of good catches. The *Jini Maru's* operator contacted about 60 ships every day, which he claimed was somewhat lower than the average for a regular commercial tunaboat. We were told that there were numerous groups of boats, usually all from the same locality, which reported in code in an effort to keep down the competition for any schools that they might discover, and after seeing the congestion on the fishing grounds we could sympathize with this attitude. It appeared, however, that for the most part these attempts at secrecy were not very successful.

Although it was said, and apparently with considerable truth, that Albacore on these grounds surfaced mostly in the early morning and late afternoon, intensive scouting was usually carried on from dawn to dusk. Occasionally, in bright weather, a short break would be taken around midday. At night, if the fishing had been good in the evening, the ship would be hove to until sunup, but after an unsuccessful day

Japanese live-bait fishing vessel on the baiting ground in Tokyo Bay. **Jini Maru,** whose operations are described in this article is of similar character.

most of the night would be spent in running toward the scene of the latest good catches reported by radio.

Fishing Operations

● In this fishery schools are spotted mostly by the accompanying birds, although drift logs are sometimes also good indicators of fish. We watched the successful fishing of a mixed school of Skipjack and 30- to 40-pound Bigeye which was keeping close company with a huge basking shark, and also the generally unproductive fishing of several schools of small Skipjack which though unaccompanied by birds had revealed their presence by the "boiling" at the surface caused by their feeding. Dolphin were also fished enthusiastically, for by custom the money they bring all goes to the crew's share.

When a bird flock was sighted, the *Jini Maru* would head into it, the baitmen tossing out sardines one at a time while all hands strained their eyes for the sight of the first fish breaking water. When fish were seen close by, the engine was stopped and attention shifted to the trolling lines. These were armed with rubber squid lures and weighted with small lead sinkers which took them down as the ship slowed. Usually not until there was a strike on the trolling lines did the fishermen get out on the sponson and the spray system begin shooting water out from closely-spaced bamboo nozzles all along the port side and around the stern and the bowsprit.

The Albacore fished on the two trips were of very uniform size, running 18 to 22 pounds. They were fished with two-pole rigs, and of course no attempt was made to wing them, as is the custom when fishing Skipjack. While fishing was going on, the cook-boys carried buckets of bait through the hail of crashing Albacore from the bait well to the baitmen's live-boxes. Fishing was done only on the port side, except at the bow and stern. Squids made of cow horn were the overwhelming favorites for Albacore fishing. When the fish ceased biting on the squids, the boys would deliver supplies of bait to the fishermen in small pails and an attempt would be made to keep the school biting on bait hooks.

Tagging Technique

● The two tagging teams, each made up of one of the American observers and his Japanese counterpart, tagged Albacore at top speed from the time the first fish hit the deck until the school stopped biting. The tagger knelt on the deck, where his partner, having found a specimen that was neither too obviously injured nor too obsterperous, would jam the Albacore's head between the tagger's thighs. The plastic tube tag was quickly thrust through the back of the fish just behind the second dorsal fin with a hollow steel needle, the ends were knotted together securely and trimmed close to the knot with scissors, and then the knot was pulled under the skin and into the tissues of the fish. The roving member of the team then heaved the fish over the side and grabbed another one. The work had to be done as rapidly as possible because of the fast pace and short duration of the fishing, the small proportion of the fish that were suitable for tagging after having been flipped onto the deck, and the generally short survival time of tuna out of the water. In many cases the Albacore seemed to be stunned and lay quiet for about half a minute after capture, but woe to the tagger who was slow with his needle

Griffith MARINE LINE

...Gets rid of the JERK!

LIVE NEOPRENE SNUBBERS

Gets rid of damaging jerks, jolts, shocks. Special formula neoprene withstands prolonged exposure to sun and salt spray.

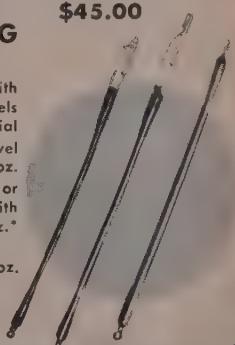
MOORING SNUBBER
Insert into mooring or lashing rope.
Has scores of uses.
Length 22" Diameter ½"
Tested Strength 1,000 lbs.
$2.95

TOW LINE OR ANCHOR SNUBBER
Clamp or chain into anchor line or tow line to absorb pounding of waves.
Length 7' Diameter 2"
Tested Strength 4,000 lbs.
$45.00

TROLLING TUBING
3/8" O.D. x 1/8" I.D. . . . . 16¢ ft.
7/16" O.D. x 1/8" I.D. . . . 17¢ ft.

NEW DELUXE TUNA TROLLING TUBING
1/2" O.D. x 3/32" I.D.
Ocean-tested for two years.
35¢ ft.

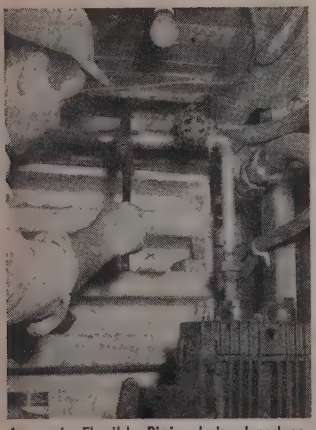
TROLLING SNUBBERS
Standard 14" length with heavy metal line swivels and snaps for commercial fishing. Solid eye, swivel end . . . . . $10 doz.
Kolstrand double snap or improved No. 9 snap with swivel end . . . . . $12 doz.*
*With ball bearing line swivels . . . . $18 doz.



● AT YOUR MARINE DEALER
. . . or write for literature
GRIFFITH RUBBER MILLS • 2439 N. W. 22nd Avenue • PORTLAND 10, OREGON

This scallop fishing boat averages 250 days a year at sea.

"Our Piping Troubles Ended When We Changed To Aeroquip Hose Lines"



Aeroquip Flexible Piping helped reduce installation time when a new diesel engine was installed in the *New Bedford*. Using Aeroquip, it took only minutes for Chief Engineer J. Giffin to assemble and install this engine fuel line.

REPORTS J. GIFFIN, CHIEF ENGINEER ON FISHING BOAT *NEW BEDFORD*

Since March, 1956, Aeroquip Hose Lines have been used for all fuel, lube oil, air, fresh and salt water applications on the deep sea fishing boat *New Bedford*. Despite rough usage and exposure to damage from salt water, weather and vibration, there hasn't been a single failure of Aeroquip Flexible Piping.

Aeroquip Flexible Piping offers another important advantage: Because all Aeroquip Fittings are reusable, replacement lines can be made in a matter of minutes, even at sea. For complete information, write today for Marine Catalog No. 301.

Aeroquip

REG. TRADEMARK

AEROQUIP CORPORATION, WESTERN DIVISION
BURBANK, CALIFORNIA
LOCAL REPRESENTATIVES IN PRINCIPAL CITIES IN U. S. A. AND ABROAD
AEROQUIP PRODUCTS ARE FULLY PROTECTED BY PATENTS IN U. S. A. AND ABROAD

and allowed the fish to recover be he had the knot secured! Riding tride a 20-pound Albacore in frenzied flurry on a slippery d could rival bronc-busting for thr spills, and contusions.

The time spent in fishing any sch was very short, 15 to 20 minutes most and usually much less, and dom was it possible to get a secc rise out of a school that had stopp biting. It appeared, and the fish men averred, that the schools w all quite small. Getting a load of f aboard was thus a matter of taking to 4 tons at a crack from a large nu ber of schools. Getting any respe able number of fish from a sch was made even more difficult by t hot competition on the grounds. Ge erally as soon as one boat raised school one or more others scouting the vicinity would head for it, swi close in alongside, and try to take t school away. The fishermen said th such raiders rarely got away with t main part of the school, but they oft did manage to break off part of it a thus cut down the catch of the fi boat on the scene. Such piracy seer to be accepted as a sort of game, b it is thought to make for poor fishir in an area where the schools are beir hounded by too many competing ve sels. Our observations seemed to sul stantiate this view, for the best fishir found by the *Jini Maru* was o grounds where she was the first a rival and could fish the schools sh found without interference. Inciden ally, the competition is often so kee that a vessel finding a promising dri log will secure it with a line to pre vent other boats from cutting betwee the log and its discoverers.

Share System

● The decision as to when and wher to come in from a trip depends, o course, on how the bait and ice sup plies hold up, on the daily reports o landings and auction prices at variou ports, and on where bait is available i relation to the probable area of opera tions of the next trip. The day seem past, as the fishermen wryly remarked when boats came in from the Albacor grounds because they had a full load In general the trips average about 1(days to 2 weeks. Turn-around time is very short. A vessel coming into port in the morning will be unloaded, fueled, iced, and provisioned by early afternoon and will sail in time to reach the baiting ground early the next morning. It was customary on the *Jini Maru* to dole out 1,000 yen ($2.75) to each man as spending money for each day in port. Even in Japan this is barely enough for a few glasses of beer, a meal or two, and a movie. The crew of the *Jini Maru*

were paid a guaranteed salary by the Prefecture of 8,000 yen ($22.00) a month in addition to their shares in the proceeds from the catch. The share system was as follows: 23 percent of the gross income is divided into 65 shares, of which the fishing captain gets 1.8, the paper captain 1.6, the radio operator 1.4, bow fishermen 1.3, stern fishermen 1.2, amidships fishermen 1.0, and boys 0.8 share. The crew pay for their food at the rate of 100 yen (about 27 cents) per day per man.

On our first trip the *Jini Maru* brought in 56 tons of fish, which was auctioned at 470 yen per *kan* (8.27 pounds) for a gross of about $18,300. This was considered a better than average trip. Our second cruise took only about 16 tons and marked the end of the vessel's fishing primarily for Albacore for the year. By that time (the last week of June) the Albacore schools had moved off to the eastward so far that only larger ships of 200-300 tons could continue to fish them, and the Skipjack, concentrating in the area of contact of the warm Kuroshio with the cold currents off northeastern Honshu, were beginning to offer good fishing.

Although the number of tagged Albacore released from the *Jini Maru* was less than we had hoped for, the modest success of the cooperative venture has received considerable publicity in Japanese tuna fishing and research circles and appears to have aroused a gratifying degree of interest. Plastic tube tags applied by the method employed at POFI and on the West Coast are now being used by the Kanagawa Prefecture laboratory to tag longline-caught tunas, and provided budgetary problems can be solved, there are good prospects that the Japanese government will sponsor a large-scale Albacore tagging effort in the near future.

DISPLAY COP

JOHN W. VAN LANDINGHAM

A MODIFICATION OF THE KNUDSEN METHOD FOR SALINITY DETERMINATION

EXTRAIT DU JOURNAL DU CONSEIL INTERNATIONAL
POUR L'EXPLORATION DE LA MER
VOL. XXII. No. 2. 1957

A Modification of the Knudsen Method for Salinity Determination

By

John W. Van Landingham,

Physical Science Aid,
Pacific Oceanic Fishery Investigations, Honolulu, T. H.

Prior to 1955 the conventional Mohr titration for chlorides was in use at the Pacific Oceanic Fishery Investigations laboratory in conjunction with Knudsen's methods for sea-water analysis (Oxner, 1946). In general, reproducibility at the end point was within the range of 0·05% to 0·1% when determinations were made by a skilled operator. Although this degree of precision is considered adequate for the needs of this laboratory, there are limitations to the method.

The Mohr method, as applied to sea water, involves reducing titration time by choosing an empirical and transitory end point in place of a stoichiometric one. As a result, the titration is highly sensitive to changes in such elements of the technique as rate of mixing, velocity of titrant addition, etc.

Another related difficulty is the gross size of the silver chloride aggregates formed during a standard Mohr titration. This heavy flock drastically reduces the surface area of the precipitate and entrains considerable quantities of the solution in the interstices, retarding the ionic exchange at the interface between silver chloride and mother liquor, and resulting in considerable end point variability. And because the Mohr end point is not permanent, a time factor, in addition to depth of colour, must be considered when determining it (U. S. Navy Hydrographic Office, 1949). Thus the entire operation falls into the category of an art, and coping with so many variables taxes the abilities of even skilled analysts.

A third factor is the sensitivity of the end point. The colloidal aggregates of silver chloride partially obscure the initial development of indicator colour, and the re-solution of silver chromate precipitated by local excesses of titrant proceeds somewhat slowly (Kolthoff and Sandell, 1949). The over-all effect, then, is a loss of indicator sensitivity.

It was felt that on theoretical grounds most, if not all, of the above-mentioned difficulties would be eliminated by the use of adsorption indicators, such as di-chlorofluorescein, in the presence of a protective colloid, as used by FAJANS (cf. TREADWELL and HALL, 1948). Adsorption indicators are organic dyes which are adsorbed on the surface of silver-chloride suspensoids on which the adsorbed Cl^- ion has been replaced by the Ag^- ion. It is believed that such dyes owe their characteristic colour to the frequency at which the chromophoric group resonates in the molecular system (BREWSTER, 1953) and that a change in potential external to the molecule (such as occurs at a precipitometric end point) modifies the frequency of resonance and imparts a change in colour to the dye.

Adsorption indicators require a protective colloid (such as starch) to inhibit flocculation of particulate silver chloride. This increases the solid-liquid interface enormously, facilitating ionic exchange and resulting in a non-fading end point. The colour change takes place on the surface of every dispersed silver-chloride particle, thus increasing the sensitivity markedly. It must be remembered, however, that the photo-chemical reduction of ionic silver is accelerated by the sensitizing effect of the dyes (KOLTHOFF and STENGER, 1947).

Apparently there was little or no interest in FAJANS's method among early investigators in the field of marine chemistry. SARUHASHI (1953) reports a micro-method using uranin (di-chlorofluorescein), which has a mean deviation of $0{\cdot}01\,^0/_{00}$ on a 1·5 ml. sample. More recently, however, COX (1954) adapted the method to the determination of salinity in sea water. He used sodium salt of fluorescein and starch as a protective colloid and reported a noticeable increase in precision over the Mohr method. Previous investigators have stressed the fact that the colour change must take place near the stoichiometric end point. However, considering the flexibility of the Knudsen technique, I believe that this is an unnecessary limitation. A series of experiments was undertaken with the following dyes: —

1. Fluorescein
2. Di-chlorofluorescein
3. Indigo disulphonate
4. Brilliant yellow
5. Tropeolin 000 (orange 1)
6. Bromophenol blue
7. Nile blue
8. Alizarin red S. (Alizarin mono sodium sulfonate)
9. Phenosafranin (after BERRY and DURRANT, 1933, quoted by KOLTHOFF and STENGER, 1947)

Most of the above compounds can be used in the determination of salinity, but all except phenosafranin have undesirable characteristics. The fluorescein dyes and brilliant yellow were rejected because of instability in contact with starch solution over long periods of time. Indigo disulphonate changes from blue to colourless and is not adsorbed on the micelles. Techniques using bromophenol blue (TREADWELL and HALL, 1948, quoting KOLTHOFF) are somewhat involved. Resonance excitation in nile blue takes place too far from the stoichiometric end point. Alizarin red S., when adjusted to the proper pH, gives a distinct colour change close to the stoichiometric end point. It is relatively stable in preserved starch solution, and with care and skill maximum stirring speed can be used throughout the titration. However,

the dye is slightly unstable in sea water and approximately 10 minutes' contact with sea water prior to titration results in etiolation of the end point.

Phenosafranin[1]) was the best among those considered in stability, sharpness of end point, and degree of contrast between the two colour phases. It is less sensitive to pH changes and more stable in sea water than Alizarin red S. and appears to be in all respects eminently suited to salinity analysis. The indicator solution is prepared in the following manner: —

1. To 700 ml. of distilled water add 1 g. of sodium benzoate, U. S. P. powder.
2. Bring solution to a vigorous boil.
3. Triturate 40 g. of soluble starch to a very thin paste with cold distilled water.
4. Slowly add the cold starch suspension to the boiling benzoate solution.
5. Continue to boil for 2 to 5 minutes after addition of starch solution.
6. Remove from heat and filter while hot through glass wool and cotton.
7. To 50 ml. of cold distilled water add 2·5 g. of phenosafranin[2]) dye. Stir thoroughly and then add the suspension slowly to the hot starch solution.
8. Mix well, and when partially cooled make up to 1,000 ml. volume with distilled water. Use 1 ml. per determination.
9. To each sample add a minimum of 10 ml. of chloride-free distilled water, to inhibit foaming.

As a further refinement the end point has been made virtually insensitive to fluctuations in quality of ambient light by the following techniques: —

1. The immediate titration area is flooded as much as possible with fluorescent light.
2. One half of the outer wall surfaces of titration beakers are painted with white enamel.
3. Light from a Bausch and Lomb spherical microscope lamp is beamed horizontally through the unpainted portion of the titration beaker and at a level of approximately 1 inch above the maximum height of liquid. Thus, the upper surface of the solution is bathed completely in diffuse light. (Any *white* light of sufficient intensity and delivered horizontally is satisfactory.)

We have found that the use of such techniques facilitates detection of the end point and markedly decreases the influence of external fluctuations in light quality, in both MOHR's and FAJANS's methods.

Routine determination follows the Knudsen method, with the exception

[1]) The adsorption behaviour of phenosafranin apparently differs from the classical concept of such indicators wherein adsorption takes place at the equivalence point simultaneously with the change in indicator colour (BREWSTER, 1953). Evidence indicates that phenosafranin is adsorbed in its primary colour phase (pink) as rapidly as silver-chloride micelles are formed. The secondary phase (blue) appears at the equivalence point subsequent to adsorption.

[2]) Phenosafranin (3, 6 di-amino-phenyl-phenazine chloride) is a biological stain and photographic anti-fog. It is manufactured by the Analine Division of Allied Chemical & Dye Corporation, N.Y., color index #840, catalogue #NA–685.

Table 1

Comparative performance data, Mohr method *versus* modified Fajans method

	Mohr Method				Modified Fajans method			
	Titration (double millilitres)	Alpha	k	Cl ‰	Titration (double millilitres)	Alpha	k	Cl ‰
Copenhagen water (19·379‰)	19·326	–	–	–	–	–	–	–
–	19·328	–	–	–	–	–	–	–
–	19·321	–	–	–	–	–	–	–
Average	19·325	+0·054	–	–	–	–	–	–
Copenhagen water (19·375‰)	–	–	–	–	19·338	–	–	–
–	–	–	–	–	19·339	–	–	–
–	–	–	–	–	19·331	–	–	–
Average	–	–	–	–	19·336	+0·039	–	–
Sea water A	19·301	–	–	–	19·324	–	–	–
–	19·300	–	–	–	19·326	–	–	–
–	19·301	–	–	–	19·321	–	–	–
–	19·302	–	–	–	19·322	–	–	–
–	19·306	–	–	–	19·322	–	–	–
–	19·301	–	–	–	19·322	–	–	–
–	19·306	–	–	–	19·321	–	–	–
–	19·310	–	–	–	19·331	–	–	–
–	19·301	–	–	–	19·326	–	–	–
–	19·305	–	–	–	19·331	–	–	–
Average	19·303	–	+0·06	19·36	19·325	–	+0·04	19·37
Mean deviation	0·0027	–	–	–	0·0032	–	–	–
% deviation	0·014%	–	–	–	0·016%	–	–	–
Sea water B	18·908	–	–	–	18·930	–	–	–
–	18·913	–	–	–	18·929	–	–	–
–	18·912	–	–	–	18·931	–	–	–
–	18·906	–	–	–	18·941	–	–	–
–	18·918	–	–	–	18·929	–	–	–
–	18·905	–	–	–	18·931	–	–	–
–	18·921	–	–	–	18·937	–	–	–
–	18·915	–	–	–	18·929	–	–	–
–	18·907	–	–	–	18·936	–	–	–
–	18·918	–	–	–	18·931	–	–	–
Average	18·912	–	+0·06	18·98	18·932	–	+0·05	18·98
Mean deviation	0·0047	–	–	–	0·0032	–	–	–
% deviation	0·025%	–	–	–	0·017%	–	–	–
Sea water C Operator #1	19·292	–	–	–	–	–	–	–
–	19·291	–	–	–	–	–	–	–
–	19·291	–	–	–	–	–	–	–
Average	19·291	+0·054	+0·06	19·35	–	–	–	–
Mean deviation	0·003	–	–	–	–	–	–	–
% deviation	0·002%	–	–	–	–	–	–	–
Sea water C Operator #2	–	–	–	–	19·361	–	–	–
–	–	–	–	–	19·362	–	–	–
–	–	–	–	–	19·361	–	–	–
Average	–	–	–	–	19·361	—0·002	0·00	19·36
Mean deviation	–	–	–	–	0·0003	–	–	–
% deviation	–	–	–	–	0·002%	–	–	–

of the indicator. However, a few precautions must be considered. From the standpoint of speed and efficiency, particularly in routine determinations, it is desirable to maintain maximum stirring speed throughout the entire titration. In order to accomplish this, the titrant must be introduced at the extreme periphery of the rotating solution at the beaker wall. At this point the linear velocity is low enough to permit local excesses of titrant to accumulate in a thin purple streamer which precedes the final stoichiometric change. However, the onset of the end point is so sudden that, at rapid mixing speeds and maximum titrant delivery, a high degree of visual alertness is required to detect the faint streamer of colour which precedes the stoichiometric colour changes. In stead of such a technique, the solution may be titrated rapidly at a very low stirring speed until local excesses of titrant produce distinct colour changes in the solution. Stirring may then be increased to maximum and after decoloration the titration continued, dropwise at first and then with fractional drops near the end point.

Reference to the performance data (Table 1) shows that precision is comparable between the Mohr and modified Fajans methods, the two agreeing well within the limits of experimental error. The absolute accuracy of the new method as checked against Copenhagen water is certainly as good as, if not better than, the Mohr method. It should be pointed out that the titrations shown in the performance data were done with the improved lighting technique described previously. Thus, the precision indicated is greater than has been encountered in standard Mohr techniques. In spite of this improvement in the Mohr method, long-term experience with thousands of determinations performed by different operators has shown a 25% increase in output for the phenosafranin method. This is primarily due to a marked decrease in the number of faulty titrations and in the number of standardizations required. It has been shown that this method is more easily and quickly mastered by completely inexperienced personnel. Although the samples chosen for comparison in this paper differ in chlorinity by only 0·5‰, practical experience at POFI has indicated that no difficulties were encountered with samples varying in solids content from 32·5‰ (sea water) to 117·9‰ (samples from enclosed lagoon, Laysan Island, Hawaiian archipelago).

A table of the titration characteristics of the two methods is shown below.

Standard Mohr method	Modified Fajans method
1. Empirical non-permanent end point.	1. Stoichiometric permanent end point.
2. Sensitive to rate of mixing.	2. Not sensitive to rate of mixing.
3. Colour intensity continues to increase beyond the end point if titration is continued.	3. Colour intensity remains constant beyond the end point.
4. Alpha values may vary greatly with changes in ambient-light quality.	4. Alpha values remain constant with changes in ambient light.
5. Relatively large flock which is responsible for fading end point.	5. Colloidally dispersed precipitate.

Summary

A new adsorption indicator method for determining salinity of sea water is described. Experience over a period of twelve months has shown this method to be more trouble-free than the standard Mohr method. The number of determinations per man-hour has been increased, and a general increase in precision among all workers has been noted. This has been confirmed by other workers using other organic indicators of the same general type. The table of performance data has been included, not to prove the claim for greater precision, but rather to show that *accuracy* is comparable between the two methods. The author feels that superiority in precision can be proven only by a long-term statistical analysis of routine data.

References

Brewster, R. Q. "Organic chemistry." Prentice-Hall, Inc., New York, 719 pp. 1953.

Cox, R. A. "An apparatus for determining the salinity of sea water." Journ. du Cons., **20**, 1, pp. 9–17. 1954.

Kolthoff, L. M., and Sandell, E. B. "Textbook of quantitative inorganic analysis." MacMillan, New York, 570 pp. 1949.

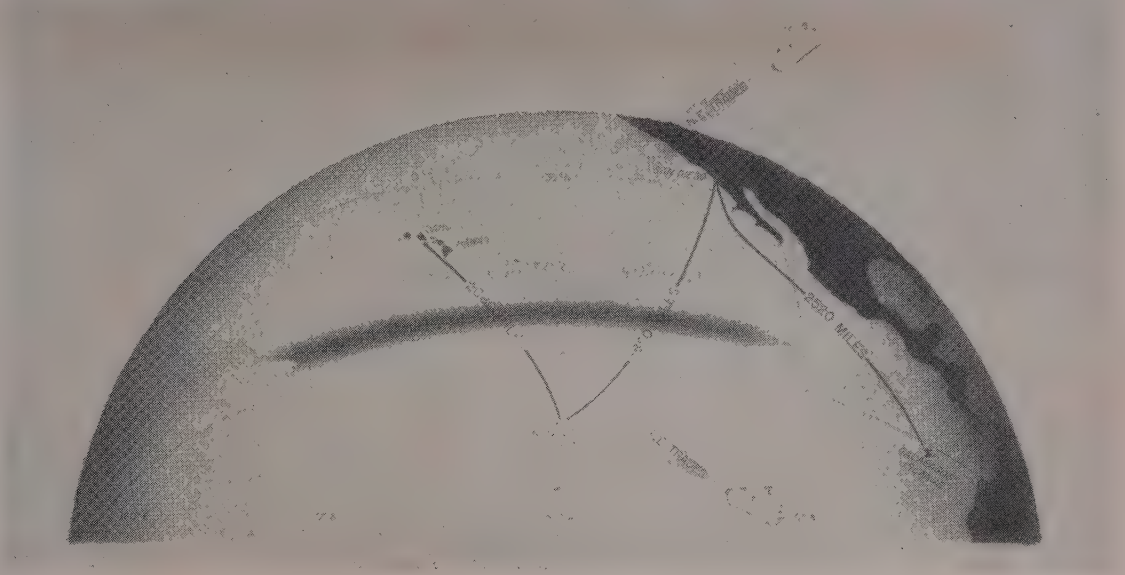
Kolthoff, L. M., and Stenger, V. A. "Volumetric analysis II." Interscience Pub. Inc., New York, 246 pp. 1947.

Oxner, M. "The determination of chlorinity by the Knudsen method." Translation published by Woods Hole Oceanographic Inst. 1946.

Saruhashi, Katsuko. "The chlorinity determination of sea water by micro-analytical method." Rec. Oceanogr. Works Japan, **1**, 2, N.S. 1953.

Treadwell, F. P., and Hall, W. T. "Analytical chemistry." Vol. 2. John Wiley and Sons, New York, 651 pp., 9th ed. 1948.

U.S. Navy Hydrographic Office. "Instruction manual for oceanographic observations at sea." H.O. Pub. 607, 74 pp. 1949.



U. S. FISH AND WILDLIFE SERVICE

Task Force in the Marquesas

Reprinted from PAN AMERICAN FISHERMAN 11(12): 6-7, 14. July 1957.

Figure 1—Tuna school at stern of M. V. Charles H. Gilbert.

U. S. FISH AND WILDLIFE SERVICE

Task Force in the Marquesas

By ROBERT C. WILSON and THOMAS S. AUSTIN

THE Pacific Oceanic Fishery Investigations (POFI) of the U.S. Fish and Wildlife Service recently used the "task force" approach in an effort to evaluate the tuna resources of the south central Pacific.

Multiple-vessel cruises were made to the region of the Marquesas Islands to obtain answers to questions concerning the availability of both surface and deep-swimming tunas, their distribution, and their relationship to their environment, the ocean. Although these cruises were primarily of exploratory nature, they produced information which affords definite conclusions of immediate interest.

The Marquesas are the most northeasterly of the islands of French Oceania. They lie about 330 miles farther from Southern California than do the Galapagos Islands (see fig. 2). This fact has, in recent years, stimulated an interest in the possible development of tuna fishing grounds in the Marquesan area by the long-range segment of the tuna clipper fleet. Such an interest is a logical development. In fact, in 1955 the M.V. *Paramount*, a San Diego-based tuna clipper, spent two weeks scouting the Marquesas group; tuna schools were reported as numerous, but the fish did not bite well.

In planning the Marquesan surveys, two periods, the southern hemisphere winter and the southern hemisphere summer, were selected in order to afford the greatest contrast in environmental conditions, and possibly in tuna abundance. A two-vessel task force was formed for the winter survey (August - September, 1956), and a three-vessel force for the survey during the Marquesan summer (January-March, 1957). The specific vessel assignments and the missions of these vessels were:

Winter: *Hugh M. Smith*—Oceanography and productivity

Charles H. Gilbert—Live-bait and longline fishing

Summer: *Hugh M. Smith*—Oceanography and productivity

Charles H. Gilbert—Live-bait fishing

John R. Manning—Longline fishing

Both of these surveys were completed; the survey area is shown in figure 3. The results of these efforts are in part summarized by the following series of questions and answers:

Q. Were there many tuna around the Marquesas, and was there a seasonal variation in their availability?

A. Skipjack were plentiful in the Marquesas during the summer months. More than three times as many schools were seen during the summer cruise as during the winter. A total of three scouting surveys were made, each following the track covering the immediate vicinity of the Marquesas group, as shown in figure 4. Results of these surveys may be summarized as follows:

Time	Total	Schools sighted Skipjack	Yellowfin	Mixed	Unidentified[1]
Mid-Sepember	26	5	—	—	21
Late January	80	40	4	4	32
Late February	89	21	7	—	61

[1] "Unidentified" schools are those where tuna were seen, but not identified as to species.

Mr. Wilson is Fishery Research Biologist, and Mr. Austin is Oceonographer, Pacific Oceanic Fishery Investigations, U.S. Fish and Wildlife Service, Honolulu, T. H.

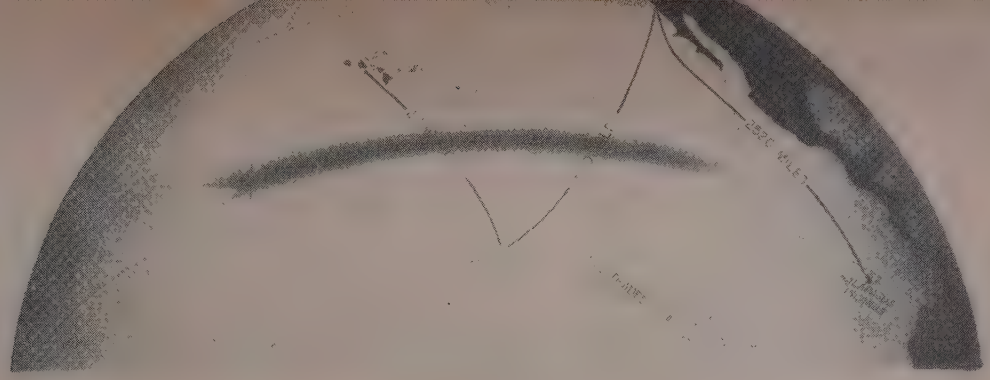


Figure 2—Distances to the Marquesas Islands.

More Questions and Answers

Q. How did the fish behave?

A. In general, the schools were wild and fast-moving. Most of the identified schools were skipjack. Typically, the skipjack schools were continually changing — segments of schools breaking off from the main body, rejoining, etc. Virtually all of the fish in schools identified as yellowfin were large, from 50 to 100 pounds in weight, and these schools were also fast-traveling.

Q. Did the tuna bite well?

A. No. During the summer cruise, 99 trials were made with live-bait on tuna schools. Fish from 36 schools responded to the point where a catch of one or more tuna was made, whereas a catch of 100 or more was made from only 12 schools. The results may be summarized as follows:

School composition	Number of trials	Catch 1 or more tuna	100 or more tuna	250 or more tuna	500 or more tuna
Skipjack	68	29	12	7	3
Yellowfin	18	2	0	0	0
Unidentified	7	0	0	0	0
Mixed, YF-SJ	5	4	0	0	0
Little tunny	1	1	0	0	0

It should be pointed out here that the catches of tuna in the table above cannot be translated into performance by a tuna clipper, because the POFI vessel was at times catching fish at a slow rate for tagging with a reduced number of men in the racks. Also, the need for covering the entire area during the visual scouting surveys did not permit fishing each school fully. Tuna bit at an equally slow rate during the winter cruise.

Q. What was the size of the tuna caught?

A: Of the total catch of 4,838 skipjack during the summer cruise, 90% were 9 pounds or under in weight, with most of the fish weighing about 6 pounds. Of the remaining 10% of larger skipjack, those weighing about 16 pounds occurred most frequently. During the winter cruise the predominant weight was 5 pounds. The yellowfin caught from schools mixed with skipjack weighed 5-6 pounds, while yellowfin from "pure" schools weighed 50-100 pounds.

Q. How many tuna were tagged?

A. We tagged 797 skipjack and 10 yellowfin using the new POFI dart tag.

Q. Is there any bait around the Marquesas?

A. Yes. There is the Marquesan sardine, which is similar in appearance to flatiron herring of Lower

(Continued on next page)

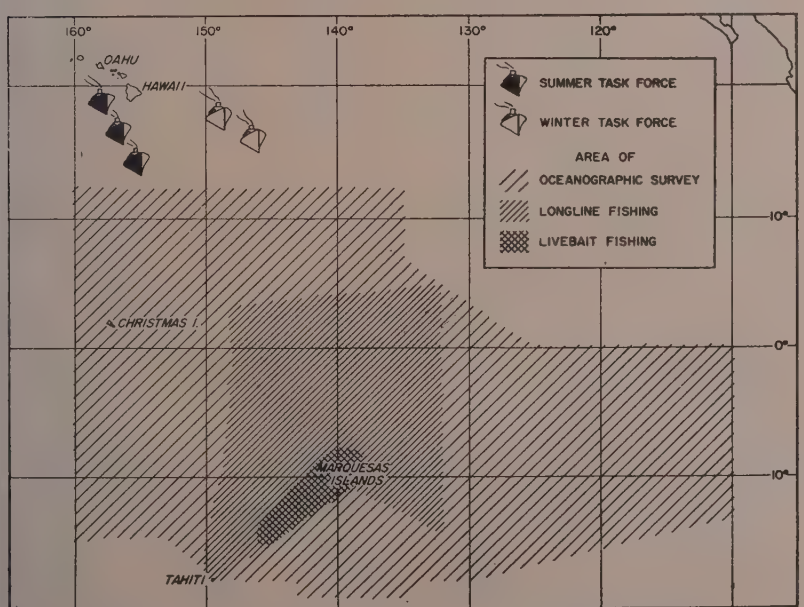


Figure 3—Survey area: POFI 1956-57 cruises to the southeast Pacific.

FAWS TASK FORCE IN THE MARQUESAS

(Continued from previous page)

California, and averages about 3½ inches in length. Also, there is a species of goatfish, slightly larger.

Q. How does the bait behave?

A. The sardines school up and return to the boat when thrown as bait. The goatfish are unsuitable for bait because they scatter and dive.

Q. How much bait was seen?

A: A large supply of sardines was observed in some of the bays. Surveys for bait were made in 16 days of the Marquesas, and varying quantities of sardines were found in 12 of them. Typically, sardines were seen during daylight hours in shallow water over sandy bottom. Six of the most productive baiting localities are listed as follows:

1. Taio Hae Bay, Nuku Hiva I. Most reliable bait source. 1,200 scoops seen, 1-24-57. Good protection from weather and short tow to vessel.

2. Anaho Bay, Nuku Hiva I. 5,000 scoops seen, 1-31-57; 500 buckets caught. Bad surge in NE weather.

3. Taipi Vai, Nuku Hiva I. 100 scoops caught, 2-4-57. No general survey made. Good protection from weather, but long tow to vessel.

4. Haka Ehu, Nuku Hiva I. 130 scoops caught. 3-5-57. No general survey made. Bad surge in NE weather.

5. Taa Huku Bay, Hiva Oa I. 40 scoops caught, 1-27-57. None seen, 2-27-57. Good protection from weather.

6. Hatiheu Bay, Nuku Hiva I. 50 scoops caught, 2-8-57. Bad surge in NE weather.

Sardines of all sizes were attracted to a light at night. It was found that more were attracted to the vessel by the diffused light of a floodlight, than by intense light from a single bulb. Seven sets were made with a night net, and catches ranged from 4 to 130 scoops of sardines per set, with the average catch 44 scoops.

Q. Did the sardines survive well in the tanks?

A. Extremely careful handling was required, or a large percentage would die within 12 hours after being placed in the wells. Once settled, they milled well. When properly cared for, they survived for an extended period in the wells.

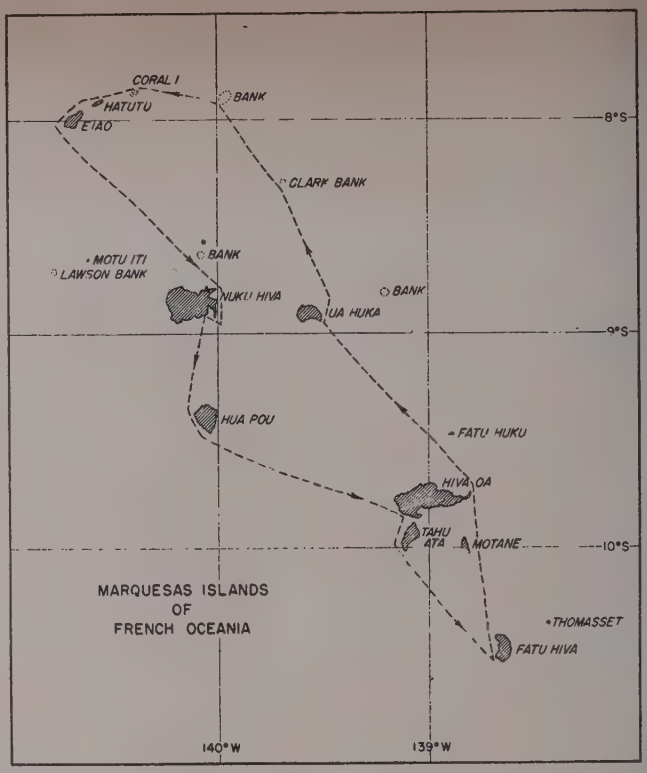


Figure 4—Track of Charles H. Gilbert in scouting for tuna schools for each of three periods including (1) September 7-15, 1956, (2) January 25-30, 1957, and (3) February 23-March 1, 1957.

Q. What did the oceanographic surveys reveal?

A. The currents in the general region of the Marquesas and the Tuamotus were setting onto the islands from the southeast during the winter survey. Those observations which tell us about the potential tuna forage in the area indicated that the waters downstream from the islands were relatively rich. Analysis of the data from the summer survey are not yet completed.

Q. What about the deep-swimming tuna?

A. Some good catches of large yellowfin (7-8 per hundred hooks) were made in the immediate vicinity of the Marquesas during the summer cruise. Longline catches in the rest of the survey area were small, both in summer and winter.

Q. Do you plan additional surveys in the Marquesas?

A: Yes. We plan to return to the Marquesas in order to study in greater detail the extent of the season of greatest availability of surface schools of tuna, and to learn more about their behavior. *

DISPLAY COPY

YELLOWFIN TUNA SPAWNING IN THE CENTRAL EQUATORIAL PACIFIC

BY HEENY S. H. YUEN AND FRED C. JUNE

FISHERY BULLETIN 112

From Fishery Bulletin of the Fish and Wildlife Service

VOLUME 57

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*

FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE

YELLOWFIN TUNA SPAWNING IN THE CENTRAL EQUATORIAL PACIFIC

By Heeny S. H. Yuen and Fred C. June

FISHERY BULLETIN 112
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 57

UNITED STATES GOVERNMENT PRINTING OFFICE • WASHINGTON • 1957

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 15 cents

ABSTRACT

Material for this report was furnished by 740 laboratory determinations, supplemented by field determinations, of the stage of maturity of ovaries of yellowfin tuna (*Neothunnus macropterus*) caught in the central equatorial Pacific. The usual length at sexual maturity of yellowfin in this area was found to be about 120 cm., although yellowfin as small as 70 cm. may be mature. Spawning was found to occur throughout the area surveyed (approximately 10° N. to 8° S. latitude, 120° W. to 180° longitude). Other studies have indicated that this area is but part of a band of yellowfin spawning grounds which covers the entire equatorial Pacific.

In this investigation, residual eggs in various stages of resorption were examined and described. Of 25 ovaries examined, 22 were found to be infested with unidentified nematodes ranging from 0.5 to 4 cm. in length. The number of worms in an ovary was usually less than five, and the infestation did not appear serious enough to affect the function of the ovary.

CONTENTS

	Page
Sources of data	251
Size of fish at first spawning	257
Locality of spawning	258
Time of spawning	259
Description of stages in resorption of residual eggs	260
Occurrence of nematodes in the ovaries	262
Summary	263
Literature cited	263

YELLOWFIN TUNA SPAWNING IN THE CENTRAL EQUATORIAL PA

By HEENY S. H. YUEN and FRED C. JUNE, *Fishery Research Biologists*

Because of the need for more knowledge about the spawning habits of the yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel), a study was initiated as part of the tuna-research program of the Fish and Wildlife Service's Pacific Oceanic Fishery Investigations (POFI). Previous studies have been made of the reproduction of this species in various parts of the Pacific—by Schaefer and Marr (1948) and by Mead (1951) in Central American waters, by Bini (1952) off Chile and Peru, by June (1953) in Hawaiian waters, by Marr (1948) in the Marshall Islands, by Shimada (1951) near Kapingamarangi Island (1° N., 155° E.), and by Wade (1950 and 1951) in the Philippine Islands. This report is based on data from the central equatorial Pacific.

In this study we have investigated the time and place of spawning and the size of the fish at sexual maturity. Stages in the resorption of ripe eggs that were not spawned are incidentally described. The appearance of nematodes in the ovaries is noted, and its effect on egg production is discussed.

The research staff and vessel personnel assisted in the collection of ovaries and field data; Richard Shomura helped process the ovaries; Wilvan Van Campen translated the Japanese data; and Tamotsu Nakata prepared the illustrations.

SOURCES OF DATA

Ovaries collected on POFI exploratory-fishing trips from February 1950 to June 1954 provided most of the material for this study. The area of collection extended from 8° S. to 10° N. latitude and from 120° W. to 180° longitude.

The ovaries, preserved in 10-percent formalin, were brought back to the laboratory for
tion. A record was kept of the date and
of capture and the fork length of each
the laboratory, the eggs were classified
to physical characteristics, as immatu
mediate, maturing, or ripe, as defined
(1953). The "spawned out" category wa
because of the difficulty in defining this
since only a fraction of the total numbe
is emitted during spawning the remai
permitted fish that had recently spawn
classified into one of the four categories.

The principal features of the four cate
as follows:

Immature.—The eggs are translucent and
0.01 to 0.18 mm. in diameter.

Intermediate.—The largest eggs are semiopa
to the deposition of yolk granules; the diame
from 0.18 to 0.40 mm.

Maturing.—The largest eggs are fully opa
diameters ranging roughly from 0.40 to 1.00 m

Ripe.—The largest eggs are transparent and
diameters of about 0.76 to 1.23 mm. A pro
globule is present in each egg.

The ovaries collected after 1951 were
to an added procedure in the laborator
were examined for residual eggs—ripe
previous spawning that were not expelled
eggs were classified as being in the early
resorption if they were still translu
loose, and as being in the late stages if t
massed together and opaque or turning

The laboratory classifications of the o
arranged in table 1 by month and lo
capture, by stage of maturity, and by
fish.

TABLE 1.—*Data on 740 yellowfin tuna specimens from the central equatorial Pacific for which maturity determinations were made in the laboratory*

[Data are grouped by month of capture, by sections of 10 degrees of longitude (115° W. to 125° W., etc.), by stage of maturity, and by fish length]
[Im=immature, In=intermediate, M=mature, R=ripe]

Date	Position		Stage of maturity	Fish length
	Latitude	Longitude		
				Cm.
Jan. 26, 1951	5°37′ S.	154°56′ W.	M	113
Jan. 27, 1951	4°03′ S.	154°59′ W.	Im	104
Do	4°03′ S.	154°59′ W.	Im	96
Jan. 26, 1951	5°37′ S.	154°56′ W.	Im	78
Jan. 31, 1953	1°52′ N.	156°41′ W.	M	143
Do	1°52′ N.	156°41′ W.	In	146
Jan. 23, 1953	5°55′ N.	162°19′ W.	In	135
Do	5°55′ N.	162°19′ W.	In	132
Jan. 25, 1953	5°46′ N.	162°06′ W.	In	127
Do	5°46′ N.	162°06′ W.	Im	133
Do	5°46′ N.	162°06′ W.	Im	119
Jan. 21, 1951	0°01′ N.	158°17′ W.	Im	85
Jan. 19, 1951	8°30′ N.	158°21′ W.	Im	83
Jan. 27, 1953	5°53′ N.	161°15′ W.	Im	66
Jan. 26, 1951	3°07′ S.	171°05′ W.	In	98
Jan. 31, 1951	3°35′ S.	171°31′ W.	In	93
Jan. 26, 1951	3°07′ S.	171°05′ W.	Im	91
Do	3°07′ S.	171°05′ W.	Im	78
Jan. 29, 1951	4°26′ S.	171°15′ W.	Im	68
Feb. 11, 1953	0°09′ N.	150°00′ W.	M	149
Feb. 4, 1953	2°07′ N.	150°09′ W.	M	148
Feb. 4, 1952	0°02′ S.	154°57′ W.	M	147
Feb. 14, 1953	1°19′ S.	150°36′ W.	M	146
Feb. 12, 1953	1°13′ S.	150°11′ W.	M	145
Feb. 4, 1953	2°07′ N.	150°09′ W.	M	143
Feb. 12, 1953	1°13′ S.	150°11′ W.	M	143
Feb. 13, 1953	1°19′ S.	150°24′ W.	M	143
Feb. 4, 1953	2°07′ N.	150°09′ W.	M	139
Do	2°07′ N.	150°09′ W.	M	138
Feb. 12, 1953	1°13′ S.	150°11′ W.	M	138
Do	1°13′ S.	150°11′ W.	M	138
Feb. 13, 1953	1°19′ S.	150°24′ W.	M	137
Feb. 4, 1952	0°02′ S.	154°57′ W.	M	135
Feb. 3, 1953	2°54′ N.	150°19′ W.	In	152
Feb. 13, 1953	1°19′ S.	150°24′ W.	In	150
Feb. 4, 1952	0°02′ S.	154°57′ W.	In	148 or 140
Feb. 4, 1953	2°07′ N.	150°09′ W.	In	142
Feb. 13, 1953	1°19′ S.	150°24′ W.	In	142
Feb. 3, 1953	2°54′ N.	150°19′ W.	In	141
Feb. 10, 1953	1°04′ N.	151°05′ W.	In	141
Feb. 1, 1952	4°04′ N.	154°56′ W.	In	140
Feb. 17, 1953	2°56′ S.	150°08′ W.	In	138
Feb. 2, 1953	3°49′ N.	150°07′ W.	In	136
Feb. 1, 1952	4°04′ N.	154°56′ W.	In	129
Do	4°04′ N.	154°56′ W.	In	128
Feb. 2, 1953	3°49′ N.	150°07′ W.	Im	140
Feb. 19, 1953	6°08′ S.	150°09′ W.	Im	136
Feb. 1, 1952	4°04′ N.	154°56′ W.	Im	126
Do	4°04′ N.	154°56′ W.	Im	123
Do	4°04′ N.	154°56′ W.	Im	118
Do	4°04′ N.	154°56′ W.	Im	114
Do	4°04′ N.	154°56′ W.	Im	108
Feb. 5, 1952	1°20′ S.	155°06′ W.	M	148
Feb. 3, 1953	1°59′ N.	157°31′ W.	M	148
Feb. 5, 1952	1°20′ S.	155°06′ W.	M	147
Do	1°20′ S.	155°06′ W.	M	143
Feb. 3, 1952	1°20′ N.	155°03′ W.	M	142
Feb. 5, 1952	1°20′ S.	155°06′ W.	M	139
Feb. 3, 1953	1°59′ N.	157°31′ W.	M	139
Do	1°59′ N.	157°31′ W.	M	138
Do	1°59′ N.	157°31′ W.	M	134
Feb. 1, 1953	1°57′ N.	157°32′ W.	M	133
Feb. 3, 1953	1°59′ N.	157°31′ W.	M	130
Feb. 3, 1952	1°20′ N.	155°03′ W.	M	126
Feb. 3, 1953	1°59′ N.	157°31′ W.	M	124
Feb. 5, 1952	1°20′ S.	155°06′ W.	M	76
Feb. 1, 1953	1°57′ N.	157°32′ W.	In	142
Feb. 5, 1952	1°20′ S.	155°06′ W.	In	140
Feb. 3, 1953	1°59′ N.	157°31′ W.	In	140
Do	1°59′ N.	157°31′ W.	In	138
Feb. 5, 1952	1°20′ S.	155°06′ W.	In	137
Feb. 2, 1952	2°46′ N.	155°10′ W.	In	136
Feb. 3, 1953	1°59′ N.	157°31′ W.	In	136
Feb. 1, 1953	1°57′ N.	157°32′ W.	In	135
Feb. 3, 1953	1°59′ N.	157°31′ W.	In	135
Feb. 5, 1953	3°51′ N.	159°26′ W.	In	134
Feb. 3, 1953	1°59′ N.	157°31′ W.	In	133
Feb. 6, 1952	2°42′ N.	155°05′ W.	In	132
Feb. 1, 1953	1°57′ N.	157°32′ W.	In	131
Feb. 3, 1953	1°59′ N.	157°31′ W.	In	131
Feb. 6, 1952	2°42′ N.	155°05′ W.	In	130
Feb. 1, 1953	1°57′ N.	157°32′ W.	In	130
Feb. 3, 1953	1°59′ N.	157°31′ W.	In	130
Feb. 4, 1951	3°52′ N.	159°20′ W.	In	98
Feb. 5, 1953	3°51′ N.	159°26′ W.	Im	123
Feb. 3, 1953	1°59′ N.	157°31′ W.	Im	120
Feb. 11, 1951	0°22′ S.	160°01′ W.	Im	112
Feb. 10, 1951	0°22′ S.	160°01′ W.	Im	110
Feb. 5, 1953	3°51′ N.	159°26′ W.	Im	107
Do	3°51′ N.	159°26′ W.	Im	105
Feb. 3, 1953	1°59′ N.	157°31′ W.	Im	104
Feb. 16, 1951	0°22′ S.	160°01′ W.	Im	91
Feb. 21, 1951	5°53′ N.	162°05′ W.	Im	90
Feb. 11, 1951	0°22′ S.	160°01′ W.	Im	86
Feb. 21, 1951	5°53′ N.	162°05′ W.	Im	85
Feb. 4, 1951	3°52′ N.	159°20′ W.	Im	83
Feb. 21, 1951	5°53′ N.	162°05′ W.	Im	81
Feb. 16, 1951	1°51′ N.	157°20′ W.	Im	75
Feb. 17, 1951	3°52′ N.	159°20′ W.	Im	75
Feb. 19, 1951	3°52′ N.	159°20′ W.	Im	74
Feb. 22, 1951	5°53′ N.	162°05′ W.	Im	74
Feb. 12, 1951	3°52′ N.	159°20′ W.	Im	73
Feb. 13, 1951	1°51′ N.	157°20′ W.	Im	72
Feb. 8, 1950	4°30′ S.	172°10′ W.	M	120
Feb. 5, 1951	3°07′ S.	171°05′ W.	M	108
Feb. 11, 1950	2°50′ S.	171°40′ W.	Im	125
Feb. 10, 1952	3°15′ S.	171°30′ W.	Im	80
Feb. 8, 1950	4°30′ S.	172°10′ W.	Im	78
Feb. 5, 1951	3°07′ S.	171°05′ W.	Im	67
Feb. 18, 1952	0°02′ N.	179°48′ E.	M	144
Do	0°02′ N.	179°48′ E.	M	142
Feb. 20, 1952	2°39′ S.	179°54′ E.	M	140
Feb. 21, 1952	4°03′ S.	179°58′ E.	M	140
Feb. 20, 1952	2°39′ S.	179°54′ E.	M	138
Feb. 21, 1952	4°03′ S.	179°58′ E.	M	138
Feb. 16, 1952	3°00′ N.	180°00′	M	133
Feb. 19, 1952	1°18′ S.	180°00′	M	130
Do	1°18′ S.	180°00′	M	128
Feb. 23, 1952	6°47′ S.	179°59′ W.	In	134
Feb. 24, 1952	8°00′ S.	179°56′ E.	In	132
Mar. 15, 1953	1°00′ N.	140°00′ W.	R	146
Do	1°00′ N.	140°00′ W.	R	143
Mar. 12, 1953	1°51′ S.	140°11′ W.	R	141
Mar. 11, 1953	1°48′ S.	139°59′ W.	M	168
Mar. 15, 1953	1°00′ N.	140°00′ W.	M	163
Mar. 13, 1953	1°00′ S.	140°05′ W.	M	152
Mar. 15, 1953	1°00′ N.	140°00′ W.	M	149
Mar. 18, 1953	4°12′ N.	140°20′ W.	M	149
Mar. 14, 1953	0°09′ N.	139°47′ W.	M	148
Do	0°09′ N.	139°47′ W.	M	146
Mar. 8, 1953	6°16′ S.	141°32′ W.	M	145
Mar. 13, 1953	1°00′ S.	140°05′ W.	M	144
Do	1°00′ S.	140°05′ W.	M	144
Mar. 17, 1953	3°07′ N.	140°07′ W.	M	144
Mar. 16, 1953	2°12′ N.	140°18′ W.	M	143
Mar. 10, 1953	3°25′ S.	140°03′ W.	M	142
Mar. 14, 1953	0°09′ N.	139°47′ W.	M	142
Mar. 16, 1953	2°12′ N.	140°18′ W.	M	142
Mar. 17, 1953	3°07′ N.	140°07′ W.	M	142
Mar. 11, 1953	1°48′ S.	139°59′ W.	M	141
Mar. 13, 1953	1°00′ S.	140°05′ W.	M	141
Mar. 15, 1953	1°00′ N.	140°00′ W.	M	141
Do	1°00′ N.	140°00′ W.	M	140
Mar. 18, 1953	4°12′ N.	140°20′ W.	M	140
Do	4°12′ N.	140°20′ W.	M	140
Mar. 16, 1953	2°12′ N.	140°18′ W.	M	139
Do	2°12′ N.	140°18′ W.	M	139
Mar. 17, 1953	3°07′ N.	140°07′ W.	M	139
Mar. 14, 1953	0°09′ N.	139°47′ W.	M	136
Mar. 8, 1953	6°16′ S.	141°32′ W.	M	135
Mar. 13, 1953	1°00′ S.	140°05′ W.	M	135
Mar. 12, 1953	1°51′ S.	140°11′ W.	M	134
Mar. 17, 1953	3°07′ N.	140°07′ W.	M	134
Mar. 16, 1953	2°12′ N.	140°18′ W.	M	133
Mar. 18, 1953	4°12′ N.	140°20′ W.	In	143
Mar. 4, 1953	13°31′ S.	147°08′ W.	M	140
Do	13°31′ S.	147°08′ W.	Im	74
Mar. 12, 1952	4°10′ N.	168°30′ W.	R	145
Mar. 4, 1952	6°40′ S.	169°03′ W.	M	146
Do	6°40′ S.	169°03′ W.	M	143
Mar. 8, 1952	1°20′ S.	169°00′ W.	M	143
Mar. 5, 1952	5°18′ S.	169°03′ W.	M	142
Mar. 10, 1952	1°20′ N.	169°05′ W.	M	142
Mar. 9, 1952	0°01′ N.	169°04′ W.	M	141
Mar. 8, 1952	1°20′ S.	169°00′ W.	M	140
Mar. 11, 1952	2°50′ N.	169°07′ W.	M	140
Do	2°50′ N.	169°07′ W.	M	139
Mar. 4, 1952	6°40′ S.	169°03′ W.	M	135
Mar. 9, 1952	0°01′ N.	169°04′ W.	M	132
Mar. 7, 1952	2°43′ S.	169°00′ W.	M	130
Mar. 10, 1952	1°20′ N.	169°05′ W.	M	130
Mar. 11, 1952	2°50′ N.	169°07′ W.	In	141
Mar. 6, 1952	4°02′ S.	169°04′ W.	In	126
Apr. 30, 1951	1°51′ N.	157°20′ W.	M	110

TABLE 1.—*Data on 740 yellowfin tuna specimens from the central equatorial Pacific for which maturity determinations were made in the laboratory*—Continued

Date	Position		Stage of maturity	Fish length
	Latitude	Longitude		
				Cm.
Apr. 26, 1951	1°51′ N.	157°20′ W.	M	98
Apr. 27, 1951	1°51′ N.	157°20′ W.	In	108
Do	1°51′ N.	157°20′ W.	In	96
Apr. 30, 1951	1°51′ N.	157°20′ W.	In	96
Apr. 26, 1951	1°51′ N.	157°20′ W.	In	81
Apr. 18, 1951	5°53′ N.	162°05′ W.	Im	110
Apr. 16, 1951	5°53′ N.	162°05′ W.	Im	104
Apr. 11, 1951	0°22′ S.	160°01′ W.	Im	98
Apr. 13, 1951	5°53′ N.	162°05′ W.	Im	98
Apr. 16, 1950	5°53′ N.	162°05′ W.	Im	98
Apr. 15, 1951	5°53′ N.	162°05′ W.	Im	92
Apr. 16, 1951	5°53′ N.	162°05′ W.	Im	90
Apr. 24, 1951	1°51′ N.	157°20′ W.	Im	80
Apr. 26, 1951	1°51′ N.	157°20′ W.	Im	80
Apr. 27, 1951	1°51′ N.	157°20′ W.	Im	80
Apr. 26, 1951	1°51′ N.	157°20′ W.	Im	75
Apr. 13, 1951	5°53′ N.	162°05′ W.	Im	70
May 29, 1952	7°09′ N.	119°00′ W.	R	148
May 31, 1952	4°18′ N.	119°35′ W.	M	146
Do	4°18′ N.	119°35′ W.	M	146
Do	4°18′ N.	119°35′ W.	M	135
May 23, 1954	4°55′ N.	161°19′ W.	M	151
May 28, 1954	4°02′ N.	159°34′ W.	M	146
Do	4°02′ N.	159°34′ W.	M	146
Do	4°02′ N.	159°34′ W.	M	143
May 23, 1954	4°55′ N.	161°19′ W.	M	140
May 30, 1954	3°58′ N.	159°04′ W.	M	140
May 7, 1951	3°52′ N.	159°20′ W.	M	136
May 13, 1950	1°51′ N.	157°20′ W.	M	136
May 25, 1954	4°45′ N.	160°11′ W.	M	134
May 23, 1954	4°55′ N.	161°19′ W.	M	133
May 26, 1954	4°52′ N.	159°35′ W.	M	133
May 18, 1954	6°02′ N.	162°28′ W.	M	130
May 22, 1954	5°26′ N.	161°37′ W.	M	129
May 23, 1954	4°55′ N.	161°19′ W.	M	129
May 31, 1951	6°25′ N.	162°26′ W.	M	127
May 24, 1954	4°56′ N.	160°32′ W.	M	123
May 25, 1954	4°45′ N.	160°11′ W.	M	122
May 27, 1954	4°17′ N.	160°28′ W.	M	121
May 28, 1954	4°02′ N.	159°34′ W.	M	117
May 27, 1954	4°17′ N.	160°28′ W.	M	114
May 31, 1951	6°25′ N.	162°26′ W.	M	106
Do	6°25′ N.	162°26′ W.	M	101
Do	6°25′ N.	162°26′ W.	M	100
Do	6°25′ N.	162°26′ W.	M	92
Do	6°25′ N.	126°26′ W.	M	92
May 1, 1951	1°51′ N.	157°20′ W.	M	86
May 26, 1954	4°52′ N.	159°35′ W.	In	128
May 28, 1954	4°02′ N.	159°34′ W.	In	122
May 25, 1954	4°45′ N.	160°11′ W.	In	121
May 28, 1950	5°53′ N.	162°05′ W.	In	118
May 30, 1954	3°58′ N.	159°04′ W.	In	117
May 3, 1950	4°42′ N.	160°24′ W.	In	115
May 31, 1950	6°25′ N.	162°26′ W.	In	115
May 30, 1954	3°58′ N.	159°04′ W.	In	114
May 27, 1954	4°17′ N.	160°28′ W.	In	110
May 29, 1950	6°25′ N.	162°26′ W.	In	109
May 30, 1954	3°58′ N.	159°04′ W.	In	108
May 12, 1950	1°51′ N.	157°20′ W.	In	107
May 17, 1954	5°58′ N.	162°52′ W.	In	106
May 11, 1951	5°53′ N.	162°05′ W.	In	104
May 30, 1954	3°58′ N.	159°04′ W.	In	104
May 1, 1951	1°51′ N.	157°20′ W.	In	100
May 31, 1951	6°25′ N.	162°26′ W.	In	100
May 1, 1951	1°51′ N.	157°20′ W.	In	98
May 30, 1954	3°58′ N.	159°04′ W.	In	98
May 30, 1951	6°25′ N.	162°26′ W.	In	94
May 12, 1951	6°25′ N.	162°26′ W.	In	92
May 30, 1951	6°25′ N.	162°26′ W.	In	90
May 31, 1951	6°25′ N.	162°26′ W.	In	90
May 30, 1951	6°25′ N.	162°26′ W.	In	89
May 31, 1951	6°25′ N.	162°26′ W.	In	88
Do	6°25′ N.	162°26′ W.	In	88
Do	6°25′ N.	162°26′ W.	In	88
May 28, 1950	6°25′ N.	162°26′ W.	In	85
May 31, 1951	6°25′ N.	162°26′ W.	In	82
May 17, 1954	5°58′ N.	162°52′ W.	Im	149
May 31, 1950	6°25′ N.	162°26′ W.	Im	115
May 27, 1950	5°53′ N.	162°05′ W.	Im	112
May 3, 1950	4°42′ N.	160°24′ W.	Im	111
May 17, 1954	5°58′ N.	162°52′ W.	Im	111
May 3, 1950	4°42′ N.	160°24′ W.	Im	108
Do	4°42′ N.	160°24′ W.	Im	104
May 30, 1954	3°58′ N.	159°04′ W.	Im	103
May 28, 1954	4°02′ N.	159°34′ W.	Im	102
May 17, 1954	5°58′ N.	162°52′ W.	Im	101
May 28, 1954	4°02′ N.	159°34′ W.	Im	101
May 30, 1954	3°58′ N.	159°04′ W.	Im	101
May 17, 1954	5°58′ N.	162°52′ W.	Im	100
May 30, 1951	6°25′ N.	162°26′ W.	Im	96
May 28, 1954	4°02′ N.	159°34′ W.	Im	93
May 30, 1951	6°25′ N.	162°26′ W.	Im	90
May 20, 1951	6°25′ N.	162°26′ W.	Im	88
May 24, 1954	4°56′ N.	160°32′ W.	Im	88
May 30, 1951	6°25′ N.	162°26′ W.	Im	88
Do	6°25′ N.	162°26′ W.	Im	87
Do	6°25′ N.	162°26′ W.	Im	86
Do	6°25′ N.	162°26′ W.	Im	86
May 31, 1951	6°25′ N.	162°26′ W.	Im	85
May 1, 1951	1°51′ N.	157°20′ W.	Im	83
Do	1°51′ N.	157°20′ W.	Im	82
Do	1°51′ N.	157°20′ W.	Im	81
Do	1°51′ N.	157°20′ W.	Im	80
Do	1°51′ N.	157°20′ W.	Im	80
May 7, 1951	3°52′ N.	159°20′ W.	Im	79
May 3, 1950	4°42′ N.	160°24′ W.	Im	75
May 11, 1951	6°25′ N.	162°26′ W.	Im	75
Do	6°25′ N.	162°26′ W.	Im	75
May 27, 1950	5°53′ N.	162°05′ W.	Im	74
Do	6°25′ N.	162°26′ W.	Im	74
May 30, 1953	4°26′ S.	170°09′ W.	R	134
May 31, 1953	3°27′ S.	170°12′ W.	M	149
May 28, 1953	6°51′ S.	170°02′ W.	M	148
May 30, 1953	4°26′ S.	170°09′ W.	M	144
Do	4°26′ S.	170°09′ W.	M	136
Do	4°26′ S.	170°09′ W.	M	136
Do	4°26′ S.	170°09′ W.	M	133
May 29, 1953	5°41′ S.	169°44′ W.	M	103
May 30, 1953	4°26′ S.	170°09′ W.	In	130
Do	4°26′ S.	170°09′ W.	Im	94
June 3, 1952	0°19′ N.	119°58′ W.	M	157
June 12, 1952	6°06′ N.	129°55′ W.	R	156
June 9, 1952	2°19′ N.	130°07′ W.	R	150
June 12, 1952	6°06′ N.	129°55′ W.	R	142
June 13, 1952	8°00′ N.	130°24′ W.	R	139
June 12, 1952	6°06′ N.	129°55′ W.	R	129
June 13, 1952	8°00′ N.	130°24′ W.	R	94
June 6, 1952	1°01′ S.	125°56′ W.	M	153
June 8, 1952	0°21′ N.	129°23′ W.	M	153
June 9, 1952	2°19′ N.	130°07′ W.	M	146
Do	2°19′ N.	130°07′ W.	M	135
Do	2°19′ N.	130°07′ W.	Im	142
June 1, 1951	6°25′ N.	162°26′ W.	R	90
June 7, 1954	1°52′ N.	156°47′ W.	M	152
June 2, 1954	2°29′ N.	158°22′ W.	M	147
June 1, 1954	3°04′ N.	159°13′ W.	M	146
June 9, 1954	1°47′ N.	158°16′ W.	M	142
June 1, 1954	3°04′ N.	159°13′ W.	M	140
June 2, 1954	2°29′ N.	158°22′ W.	M	138
June 7, 1954	1°52′ N.	156°47′ W.	M	126
June 1, 1951	6°25′ N.	162°26′ W.	M	118
June 5, 1950	4°42′ N.	160°24′ W.	M	99
June 1, 1951	6°25′ N.	162°26′ W.	M	90
Do	5°53′ N.	162°05′ W.	M	87
Do	5°53′ N.	162°05′ W.	M	84
Do	5°53′ N.	162°05′ W.	M	83
June 9, 1954	1°47′ N.	158°16′ W.	In	128
June 1, 1954	3°04′ N.	159°13′ W.	In	118
June 7, 1954	1°52′ N.	156°47′ W.	In	115
June 4, 1954	2°03′ N.	157°40′ W.	In	114
Do	2°03′ N.	157°40′ W.	In	112
June 1, 1954	3°04′ N.	159°13′ W.	In	110
June 4, 1950	4°42′ N.	160°24′ W.	In	110
June 8, 1954	2°01′ N.	157°09′ W.	In	108
June 4, 1954	2°03′ N.	157°40′ W.	In	100
June 8, 1954	2°01′ N.	157°09′ W.	Im	120
June 7, 1954	1°52′ N.	156°47′ W.	Im	110
June 4, 1950	4°42′ N.	160°24′ W.	Im	100
June 8, 1954	2°01′ N.	157°09′ W.	Im	94
June 6, 1951	3°52′ N.	159°20′ W.	Im	85
Do	3°52′ N.	159°20′ W.	Im	83
Do	3°52′ N.	159°20′ W.	Im	83
June 4, 1950	4°42′ N.	160°24′ W.	Im	82
June 6, 1951	3°52′ N.	159°20′ W.	Im	82
Do	3°52′ N.	159°20′ W.	Im	82
Do	3°52′ N.	159°20′ W.	Im	80
June 1, 1951	5°53′ N.	162°05′ W.	Im	77
Do	5°53′ N.	162°05′ W.	Im	76
Do	5°53′ N.	162°05′ W.	Im	76
June 3, 1950	5°53′ N.	162°05′ W.	Im	75
June 2, 1953	0°30′ S.	169°52′ W.	R	138
June 1, 1953	2°14′ S.	170°00′ W.	M	142
June 2, 1953	0°30′ S.	169°52′ W.	M	141
Do	0°30′ S.	169°52′ W.	M	133
Do	0°30′ S.	169°52′ W.	M	131
June 1, 1953	2°14′ S.	170°00′ W.	M	129
June 2, 1953	0°30′ S.	169°52′ W.	M	121
June 1, 1953	2°14′ S.	170°00′ W.	M	102
June 12, 1951	2°50′ S.	171°40′ W.	Im	135
June 17, 1951	2°50′ S.	171°40′ W.	Im	122

TABLE 1.—*Data on 740 yellowfin tuna specimens from the central equatorial Pacific for which maturity determinations were made in the laboratory*—Continued

Date	Position		Stage of maturity	Fish length
	Latitude	Longitude		
				Cm.
June 17, 1951	2°50′ S.	171°40′ W.	Im	118
June 1, 1953	2°14′ S.	170°00′ W.	Im	81
July 17, 1950	2°50′ S.	171°40′ W.	M	140
July 15, 1950	2°50′ S.	171°40′ W.	M	128
July 19, 1950	2°50′ S.	171°40′ W.	In	134
Do	2°50′ S.	171°40′ W.	Im	118
Aug. 24, 1952	4°28′ N.	139°51′ W.	M	156
Aug. 23, 1952	5°16′ N.	140°28′ W.	M	151
Aug. 24, 1952	4°28′ N.	139°51′ W.	M	151
Aug. 31, 1952	3°45′ N.	140°10′ W.	M	151
Aug. 26, 1952	2°23′ N.	140°12′ W.	M	146
Aug. 31, 1952	3°45′ N.	140°10′ W.	M	143
Aug. 28, 1952	1°00′ N.	140°22′ W.	M	139
Aug. 24, 1952	4°28′ N.	139°51′ W.	M	129
Aug. 21, 1952	7°02′ N.	140°46′ W.	M	124
Aug. 23, 1952	5°16′ N.	140°28′ W.	M	121
Aug. 28, 1952	1°00′ N.	140°22′ W.	In	157
Aug. 29, 1952	2°00′ N.	140°40′ W.	In	153 or 139
Aug. 27, 1952	1°33′ N.	140°13′ W.	In	147
Aug. 31, 1952	3°45′ N.	140°10′ W.	In	142
Aug. 26, 1952	2°23′ N.	140°12′ W.	In	141
Aug. 29, 1952	2°00′ N.	140°40′ W.	In	139
Aug. 13, 1953	0°08′ N.	154°51′ W.	M	168
Do	0°08′ N.	154°51′ W.	M	143
Do	0°08′ N.	154°51′ W.	M	143
Aug. 27, 1951	9°36′ N.	150°06′ W.	M	143 or 131
Aug. 13, 1953	0°08′ N.	154°51′ W.	M	142
Do	0°08′ N.	154°51′ W.	M	141
Do	0°08′ N.	154°51′ W.	M	138
Aug. 26, 1953	7°50′ N.	159°24′ W.	M	153
Aug. 16, 1953	4°10′ S.	155°33′ W.	M	151
Aug. 12, 1953	1°21′ N.	155°16′ W.	M	148
Aug. 19, 1953	1°31′ S.	159°53′ W.	M	144
Aug. 7, 1953	2°05′ N.	157°38′ W.	M	143
Do	2°05′ N.	157°38′ W.	M	142
Aug. 21, 1953	1°11′ N.	160°08′ W.	M	142
Aug. 25, 1953	6°10′ N.	160°02′ W.	M	142
Aug. 7, 1953	2°05′ N.	157°38′ W.	M	141
Aug. 20, 1953	0°01′ N.	159°56′ W.	M	141
Aug. 21, 1953	1°11′ N.	160°08′ W.	M	141
Do	1°11′ N.	160°08′ W.	M	141
Do	1°11′ N.	160°08′ W.	M	140
Do	1°11′ N.	160°08′ W.	M	140
Aug. 19, 1953	1°31′ S.	159°53′ W.	M	139
Aug. 25, 1953	6°10′ N.	160°02′ W.	M	139
Aug. 7, 1953	2°05′ N.	157°38′ W.	M	138
Aug. 12, 1953	1°21′ N.	155°16′ W.	M	136
Do	1°21′ N.	155°16′ W.	M	136
Aug. 19, 1953	1°31′ S.	159°53′ W.	M	136
Aug. 20, 1953	0°01′ N.	159°56′ W.	M	136
Aug. 7, 1953	2°05′ N.	157°38′ W.	M	135
Do	2°05′ N.	157°38′ W.	M	135
Aug. 12, 1953	1°21′ N.	155°16′ W.	M	135
Aug. 14, 1953	1°08′ S.	155°18′ W.	M	134
Aug. 19, 1953	1°31′ S.	159°53′ W.	M	134
Aug. 23, 1953	3°22′ N.	160°24′ W.	M	128
Aug. 7, 1953	2°05′ N.	157°38′ W.	M	126
Do	2°05′ N.	157°38′ W.	M	124
Aug. 25, 1950	6°25′ N.	162°26′ W.	M	111
Aug. 14, 1953	1°08′ S.	155°18′ W.	In	147
Aug. 19, 1953	1°31′ S.	159°53′ W.	In	142
Aug. 14, 1953	1°08′ S.	155°18′ W.	In	140
Aug. 16, 1953	4°10′ S.	155°33′ W.	In	139
Aug. 14, 1953	1°08′ S.	155°18′ W.	In	138
Aug. 18, 1953	2°56′ S.	160°14′ W.	In	138
Aug. 19, 1953	1°31′ S.	159°53′ W.	In	138
Do	1°31′ S.	159°53′ W.	In	136
Aug. 14, 1953	1°08′ S.	155°18′ W.	In	134
Aug. 18, 1953	2°56′ S.	160°14′ W.	In	132
Aug. 14, 1953	1°08′ S.	155°18′ W.	In	131
Aug. 21, 1953	1°11′ N.	160°08′ W.	In	127
Aug. 19, 1953	1°31′ S.	159°53′ W.	In	125
Aug. 21, 1953	1°11′ N.	160°08′ W.	In	111
Aug. 15, 1953	2°33′ S.	155°23′ W.	In	89
Aug. 18, 1953	2°56′ S.	160°14′ W.	Im	139
Aug. 20, 1953	0°01′ N.	159°56′ W.	Im	116
Aug. 21, 1953	1°11′ N.	160°08′ W.	Im	109
Aug. 14, 1953	1°08′ S.	155°18′ W.	Im	104
Aug. 25, 1953	6°10′ N.	160°02′ W.	Im	102
Aug. 18, 1953	2°56′ S.	160°14′ W.	Im	89
Aug. 16, 1950	3°35′ S.	171°31′ W.	M	118
Do	3°35′ S.	171°31′ W.	Im	114
Aug. 17, 1950	3°07′ S.	171°05′ W.	Im	85
Do	3°07′ S.	171°05′ W.	Im	66
Do	3°07′ S.	171°05′ W.	Im	64
Sept. 6, 1952	2°06′ N.	140°56′ W.	R	155
Sept. 9, 1952	2°33′ N.	143°22′ W.	R	136
Sept. 7, 1952	1°42′ N.	141°24′ W.	M	153
Sept. 9, 1952	2°33′ N.	143°22′ W.	M	148
Do	2°33′ N.	143°22′ W.	M	147
Sept. 3, 1952	4°04′ N.	140°09′ W.	M	146
Sept. 6, 1952	2°06′ N.	140°56′ W.	M	144
Sept. 7, 1952	1°42′ N.	141°24′ W.	M	144
Do	1°42′ N.	141°24′ W.	M	139
Sept. 2, 1952	3°05′ N.	140°02′ W.	In	152
Sept. 6, 1952	2°06′ N.	140°56′ W.	In	148
Sept. 2, 1952	3°05′ N.	140°02′ W.	In	146
Sept. 4, 1952	3°20′ N.	140°10′ W.	In	144
Sept. 7, 1952	1°42′ N.	141°24′ W.	In	140
Sept. 1, 1952	3°31′ N.	140°28′ W.	In	138
Sept. 2, 1952	3°05′ N.	140°02′ W.	In	137
Sept. 4, 1952	3°20′ N.	140°10′ W.	Im	149
Sept. 5, 1951	2°02′ N.	151°50′ W.	R	142
Sept. 13, 1952	1°22′ N.	149°54′ W.	R	137
Sept. 2, 1951	4°04′ N.	150°06′ W.	M	153
Sept. 13, 1952	1°22′ N.	149°54′ W.	M	153
Sept. 16, 1952	2°28′ N.	150°38′ W.	M	152
Sept. 4, 1951	1°59′ N.	150°12′ W.	M	148
Sept. 15, 1952	2°05′ N.	150°23′ W.	M	148
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	148
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	147
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	147
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	146
Sept. 13, 1951	2°02′ N.	153°12′ W.	M	146
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	146
Sept. 20, 1951	0°54′ N.	150°00′ W.	M	146
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	145
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	145
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	144
Do	2°57′ N.	150°17′ W.	M	143
Sept. 4, 1951	1°59′ N.	150°12′ W.	M	143
Sept. 6, 1951	2°03′ N.	153°12′ W.	M	143
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	143
Sept. 4, 1951	1°59′ N.	150°12′ W.	M	142
Do	1°59′ N.	150°12′ W.	M	142
Sept. 17, 1951	2°01′ N.	154°50′ W.	M	142
Sept. 18, 1951	2°02′ N.	153°12′ W.	M	142
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	142
Sept. 2, 1951	4°04′ N.	150°06′ W.	M	141
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	141
Sept. 5, 1951	2°02′ N.	151°50′ W.	M	141
Do	2°02′ N.	151°50′ W.	M	141
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	141
Do	2°00′ N.	151°24′ W.	M	141
Sept. 20, 1951	0°54′ N.	150°00′ W.	M	141
Sept. 2, 1951	4°04′ N.	150°06′ W.	M	140
Sept. 5, 1951	2°02′ N.	151°50′ W.	M	140
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	140
Do	2°00′ N.	151°24′ W.	M	140
Sept. 2, 1951	4°04′ N.	150°06′ W.	M	139
Do	4°04′ N.	150°06′ W.	M	139
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	139
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	139
Do	2°00′ N.	151°24′ W.	M	139
Sept. 20, 1951	0°54′ N.	150°00′ W.	M	139
Sept. 2, 1951	4°04′ N.	150°06′ W.	M	138
Do	4°04′ N.	150°06′ W.	M	138
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	138
Sept. 5, 1951	2°02′ N.	151°50′ W.	M	138
Sept. 13, 1952	1°22′ N.	149°54′ W.	M	138
Sept. 17, 1951	2°01′ N.	154°50′ W.	M	138
Sept. 19, 1951	2°00′ N.	151°24′ W.	M	138
Sept. 20, 1951	0°54′ N.	150°00′ W.	M	138
Sept. 4, 1951	1°59′ N.	150°12′ W.	M	137
Sept. 6, 1951	2°03′ N.	153°12′ W.	M	137
Do	2°03′ N.	153°12′ W.	M	137
Sept. 18, 1951	2°02′ N.	153°12′ W.	M	137
Sept. 2, 1951	4°04′ N.	150°06′ W.	M	136
Do	4°04′ N.	150°06′ W.	M	136
Sept. 5, 1951	2°02′ N.	151°50′ W.	M	136
Sept. 16, 1952	2°28′ N.	150°38′ W.	M	136
Sept. 2, 1951	4°04′ N.	150°06′ W.	M	135
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	135
Sept. 18, 1951	2°02′ N.	153°12′ W.	M	135
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	134
Sept. 5, 1951	2°02′ N.	151°50′ W.	M	133
Do	2°02′ N.	151°50′ W.	M	133
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	132
Sept. 4, 1951	1°59′ N.	150°12′ W.	M	131
Sept. 5, 1951	2°02′ N.	151°50′ W.	M	131
Sept. 6, 1951	2°03′ N.	153°12′ W.	M	131
Sept. 2, 1951	4°04′ N.	150°06′ W.	M	129
Sept. 17, 1952	3°26′ N.	151°40′ W.	M	129
Sept. 4, 1951	1°59′ N.	150°12′ W.	M	128
Sept. 3, 1951	2°57′ N.	150°17′ W.	M	115
Sept. 18, 1951	2°02′ N.	153°12′ W.	M	106
Sept. 17, 1951	2°01′ N.	154°50′ W.	M	75
Sept. 19, 1951	2°00′ N.	151°24′ W.	In	143
Sept. 17, 1951	2°01′ N.	154°50′ W.	In	142
Sept. 19, 1951	2°00′ N.	151°24′ W.	In	142

TABLE 1.—*Data on 740 yellowfin tuna specimens from the central equatorial Pacific for which maturity determinations were made in the laboratory*—Continued

Date	Position		Stage of maturity	Fish length	Date	Position		Stage of maturity	Fish length
	Latitude	Longitude				Latitude	Longitude		
				Cm.					*Cm.*
Sept. 22, 1951	1°07′ S.	150°21′ W.	In	142	Nov. 20, 1950	2°55′ N.	160°20′ W.	Im	137
Sept. 17, 1951	2°01′ N.	154°50′ W.	In	141	Nov. 23, 1950	5°04′ N.	159°03′ W.	Im	137
Do	2°01′ N.	154°50′ W.	In	141	Nov. 21, 1950	3°52′ N.	159°57′ W.	Im	136
Do	2°01′ N.	154°50′ W.	In	140	Do	3°52′ N.	159°57′ W.	Im	135
Do	2°01′ N.	154°50′ W.	In	140	Nov. 23, 1950	5°04′ N.	159°03′ W.	Im	135
Sept. 19, 1951	2°00′ N.	151°24′ W.	In	140	Nov. 16, 1950	3°52′ N.	159°20′ W.	Im	130
Sept. 17, 1951	2°01′ N.	154°50′ W.	In	139	Do	3°52′ N.	159°20′ W.	Im	130
Do	2°01′ N.	154°50′ W.	In	139	Do	3°52′ N.	159°20′ W.	Im	122
Sept. 20, 1951	0°54′ N.	150°00′ W.	In	139	Nov. 24, 1950	6°13′ N.	158°53′ W.	Im	122
Sept. 19, 1951	2°00′ N.	151°24′ W.	In	138	Nov. 6, 1950	5°53′ N.	162°05′ W.	Im	120
Sept. 17, 1951	2°01′ N.	154°50′ W.	In	137	Nov. 16, 1950	3°52′ N.	159°20′ W.	Im	120
Sept. 4, 1951	1°59′ N.	150°12′ W.	In	136	Nov. 23, 1950	4°42′ N.	160°24′ W.	Im	120
Sept. 17, 1951	2°01′ N.	154°50′ W.	In	134	Nov. 24, 1950	6°13′ N.	158°53′ W.	Im	118
Sept. 25, 1951	4°56′ S.	150°13′ W.	In	133	Nov. 23, 1950	4°42′ N.	160°24′ W.	Im	114
Sept. 17, 1951	2°01′ N.	154°50′ W.	In	131	Nov. 3, 1950	6°25′ N.	162°26′ W.	Im	110
Do	2°01′ N.	154°50′ W.	In	131	Nov. 28, 1950	5°53′ N.	162°05′ W.	Im	110
Sept. 18, 1951	2°02′ N.	153°12′ W.	In	129	Nov. 23, 1950	4°42′ N.	160°24′ W.	Im	107
Sept. 17, 1951	2°01′ N.	154°50′ W.	In	128	Nov. 2, 1950	4°42′ N.	160°24′ W.	Im	105
Sept. 2, 1951	4°04′ N.	150°06′ W.	In	127	Nov. 16, 1950	3°54′ N.	159°26′ W.	Im	104
Sept. 25, 1951	4°56′ S.	150°13′ W.	In	122	Nov. 24, 1950	4°42′ N.	160°24′ W.	Im	103
Do	4°56′ S.	150°13′ W.	Im	117	Nov. 2, 1950	4°42′ N.	160°24′ W.	Im	102
Sept. 12, 1951	1°52′ N.	155°24′ W.	M	144	Nov. 6, 1950	5°53′ N.	162°05′ W.	Im	101
Sept. 15, 1951	1°19′ N.	157°30′ W.	M	143	Nov. 22, 1950	4°42′ N.	160°24′ W.	Im	101
Sept. 12, 1951	1°52′ N.	155°24′ W.	M	138	Do	4°42′ N.	160°24′ W.	Im	99
Do	1°52′ N.	155°24′ W.	M	137	Nov. 23, 1950	4°42′ N.	160°24′ W.	Im	99
Sept. 16, 1951	1°52′ N.	156°24′ W.	M	133	Nov. 24, 1950	4°42′ N.	160°24′ W.	Im	98
Sept. 14, 1951	1°59′ N.	157°36′ W.	M	113	Nov. 17, 1950	3°52′ N.	159°20′ W.	Im	96
Sept. 12, 1951	1°52′ N.	155°24′ W.	In	144	Nov. 23, 1950	4°42′ N.	160°24′ W.	Im	94
Sept. 13, 1951	2°02′ N.	156°20′ W.	In	144	Nov. 27, 1950	5°53′ N.	162°05′ W.	Im	93
Do	2°02′ N.	156°20′ W.	In	144	Nov. 23, 1950	4°42′ N.	160°24′ W.	Im	92
Sept. 12, 1951	1°52′ N.	155°24′ W.	In	142	Nov. 27, 1950	5°53′ N.	162°05′ W.	Im	88
Sept. 13, 1951	2°02′ N.	156°20′ W.	In	141	Nov. 24, 1950	4°42′ N.	160°24′ W.	Im	87
Sept. 16, 1951	1°52′ N.	156°24′ W.	In	140	Nov. 28, 1950	5°53′ N.	162°05′ W.	Im	86
Sept. 13, 1951	2°02′ N.	156°20′ W.	In	136	Nov. 23, 1950	4°42′ N.	160°24′ W.	Im	85
Do	2°02′ N.	156°20′ W.	In	136	Nov. 24, 1950	4°42′ N.	160°24′ W.	Im	85
Do	2°02′ N.	156°20′ W.	In	136	Nov. 4, 1950	6°25′ N.	162°26′ W.	Im	83
Sept. 16, 1951	1°52′ N.	156°24′ W.	In	136	Nov. 3, 1950	6°25′ N.	162°26′ W.	Im	82
Sept. 13, 1951	2°02′ N.	156°20′ W.	In	135	Nov. 22, 1950	4°42′ N.	160°24′ W.	Im	81
Sept. 12, 1951	1°52′ N.	155°24′ W.	In	133	Nov. 2, 1950	6°25′ N.	162°26′ W.	Im	78
Sept. 15, 1951	1°19′ N.	157°30′ W.	In	124	Nov. 4, 1950	5°53′ N.	162°05′ W.	Im	77
Sept. 13, 1951	2°02′ N.	156°20′ W.	In	115	Nov. 22, 1950	4°42′ N.	160°24′ W.	Im	77
Sept. 14, 1951	1°59′ N.	157°36′ W.	In	114	Nov. 24, 1950	4°42′ N.	160°24′ W.	Im	76
Do	1°59′ N.	157°36′ W.	In	109	Do	4°42′ N.	160°24′ W.	Im	71
Do	1°59′ N.	157°36′ W.	In	93	Nov. 28, 1950	5°53′ N.	162°05′ W.	Im	68
Do	1°59′ N.	157°36′ W.	Im	104	Nov. 4, 1950	6°25′ N.	162°26′ W.	Im	63
Do	1°59′ N.	157°36′ W.	Im	96	Nov. 27, 1950	5°53′ N.	162°05′ W.	Im	63
Oct. 19, 1952	8°14′ N.	120°32′ W.	R	147	Nov. 30, 1950	6°25′ N.	162°26′ W.	Im	61
Oct. 30, 1952	3°58′ S.	120°14′ W.	In	133	Nov. 20, 1952	3°36′ S.	170°02′ W.	R	142
Oct. 31, 1952	5°36′ S.	120°25′ W.	Im	159	Nov. 11, 1950	6°25′ N.	167°32′ W.	M	153
Oct. 27, 1952	5°34′ N.	152°26′ W.	M	143	Nov. 23, 1952	1°00′ S.	169°27′ W.	M	135
Oct. 29, 1952	3°12′ N.	152°05′ W.	M	135	Nov. 24, 1952	0°04′ N.	168°48′ W.	M	132
Oct. 27, 1952	5°34′ N.	152°26′ W.	M	127	Nov. 26, 1952	2°24′ N.	168°44′ W.	In	139
Oct. 30, 1952	2°15′ N.	151°19′ W.	In	149	Nov. 19, 1952	5°00′ S.	170°08′ W.	In	131
Oct. 27, 1952	5°34′ N.	152°26′ W.	In	140	Dec. 12, 1953	4°14′ N.	154°56′ W.	In	126
Oct. 30, 1952	2°15′ N.	151°19′ W.	In	137	Do	4°14′ N.	154°56′ W.	Im	114
Oct. 27, 1952	5°34′ N.	152°26′ W.	In	135	Do	4°14′ N.	154°56′ W.	Im	114
Oct. 28, 1952	4°00′ N.	152°20′ W.	In	133	Do	4°14′ N.	154°56′ W.	Im	103
Oct. 25, 1950	7°17′ N.	157°04′ W.	M	143	Dec. 6, 1953	2°27′ N.	155°26′ W.	In	148
Oct. 31, 1950	6°25′ N.	162°26′ W.	Im	99	Dec. 11, 1953	3°31′ N.	155°23′ W.	In	147
Do	6°25′ N.	162°26′ W.	Im	95	Dec. 7, 1953	1°59′ N.	156°09′ W.	In	146
Do	6°25′ N.	162°26′ W.	Im	95	Dec. 3, 1953	1°28′ S.	155°25′ W.	In	144
Do	6°25′ N.	162°26′ W.	Im	88	Do	1°28′ S.	155°25′ W.	In	142
Nov. 1, 1952	7°33′ S.	120°21′ W.	M	138	Dec. 8, 1953	2°14′ N.	157°08′ W.	In	140
Do	7°33′ S.	120°21′ W.	In	139	Dec. 2, 1953	3°02′ S.	155°12′ W.	In	138
Do	7°33′ S.	120°21′ W.	In	127	Dec. 5, 1953	1°22′ N.	155°18′ W.	In	137
Do	7°33′ S.	120°21′ W.	In	123	Dec. 11, 1953	3°31′ N.	155°23′ W.	In	137
Do	7°33′ S.	120°21′ W.	Im	153	Dec. 6, 1953	2°27′ N.	155°26′ W.	In	136
Nov. 6, 1952	3°11′ S.	130°17′ W.	M	132	Do	2°27′ N.	155°26′ W.	In	134
Do	3°11′ S.	130°17′ W.	Im	150	Do	2°27′ N.	155°26′ W.	In	127
Nov. 3, 1952	1°00′ N.	151°26′ W.	In	[1] 145	Dec. 1, 1953	4°33′ S.	155°08′ W.	In	123
Do	1°00′ N.	151°26′ W.	In	142	Dec. 2, 1953	3°02′ S.	155°12′ W.	In	122
Nov. 2, 1952	2°13′ N.	151°51′ W.	In	135	Dec. 7, 1953	1°59′ N.	156°09′ W.	In	118
Nov. 6, 1950	5°53′ N.	162°05′ W.	M	146	Dec. 8, 1953	2°14′ N.	157°08′ W.	In	110
Nov. 7, 1950	6°13′ N.	163°05′ W.	M	134	Dec. 7, 1953	1°59′ N.	156°09′ W.	In	107
Nov. 8, 1950	6°59′ N.	163°54′ W.	M	133	Do	1°59′ N.	156°09′ W.	In	105
Nov. 9, 1950	7°24′ N.	164°23′ W.	M	133	Dec. 8, 1953	2°14′ N.	157°08′ W.	In	105
Nov. 30, 1950	6°25′ N.	162°26′ W.	M	129	Do	2°14′ N.	157°08′ W.	In	103
Nov. 9, 1950	7°24′ N.	164°23′ W.	In	143	Do	2°14′ N.	157°08′ W.	In	103
Nov. 16, 1950	3°52′ N.	159°20′ W.	In	143	Dec. 2, 1953	3°02′ S.	155°12′ W.	In	88
Nov. 24, 1950	6°13′ N.	158°53′ W.	In	140	Dec. 9, 1953	2°01′ N.	158°15′ W.	In	87
Nov. 19, 1950	1°12′ N.	160°21′ W.	In	139	Dec. 3, 1953	1°28′ S.	155°25′ W.	Im	144
Nov. 1, 1950	1°51′ N.	157°20′ W.	In	136	Dec. 7, 1953	1°59′ N.	156°09′ W.	Im	144
Nov. 21, 1950	3°52′ N.	159°57′ W.	In	134	Dec. 9, 1953	2°01′ N.	158°15′ W.	Im	144
Do	3°52′ N.	159°57′ W.	In	132	Dec. 11, 1953	3°31′ N.	155°23′ W.	Im	144
Nov. 24, 1950	6°13′ N.	158°53′ W.	In	122	Do	3°31′ N.	155°23′ W.	Im	144
Nov. 20, 1950	2°55′ N.	160°20′ W.	Im	143	Dec. 3, 1953	1°28′ S.	155°25′ W.	Im	142
Do	2°55′ N.	160°20′ W.	Im	141	Do	1°28′ S.	155°25′ W.	Im	141
Nov. 19, 1950	1°12′ N.	160°21′ W.	Im	138	Dec. 11, 1953	3°31′ N.	155 23′ W.	Im	141

[1] From length-weight relation.

TABLE 1.—*Data on 740 yellowfin tuna specimens from the central equatorial Pacific for which maturity determinations were made in the laboratory*—Continued

Date	Position		Stage of maturity	Fish length	Date	Position		Stage of maturity	Fish length
	Latitude	Longitude				Latitude	Longitude		
				Cm.					*Cm.*
Dec. 7, 1953	1°59′ N.	156°09′ W.	Im	138	Dec. 8, 1953	2°14′ N.	157°08′ W.	Im	10
Dec. 11, 1953	3°31′ N.	155°23′ W.	Im	138	Do	2°14′ N.	157°08′ W.	Im	10
Do	3°31′ N.	155°23′ W.	Im	137	Do	2°14′ N.	157°08′ W.	Im	10
Dec. 7, 1953	1°59′ N.	156°09′ W.	Im	136	Do	2°14′ N.	157°08′ W.	Im	10
Dec. 11, 1953	3°31′ N.	155°23′ W.	Im	129	Dec. 9, 1953	2°01′ N.	158°15′ W.	Im	10
Dec. 1, 1953	4°33′ S.	155°08′ W.	Im	125	Dec. 8, 1953	2°14′ N.	157°08′ W.	Im	10
Dec. 5, 1953	1°22′ N.	155°18′ W.	Im	123	Do	2°14′ N.	157°08′ W.	Im	9
Dec. 2, 1953	3°02′ S.	155°12′ W.	Im	121	Do	2°14′ N.	157°08′ W.	Im	9
Dec. 7, 1953	1°59′ N.	156°09′ W.	Im	120	Do	2°14′ N.	157°08′ W.	Im	9
Dec. 2, 1953	3°02′ S.	155°12′ W.	Im	119	Do	2°14′ N.	157°08′ W.	Im	9
Dec. 6, 1953	2°27′ N.	155°26′ W.	Im	119	Do	2°14′ N.	157°08′ W.	Im	9
Do	2°27′ N.	155°26′ W.	Im	116	Do	2°14′ N.	157°08′ W.	Im	9
Dec. 2, 1953	3°02′ S.	155°12′ W.	Im	115	Do	2°14′ N.	157°08′ W.	Im	9
Dec. 7, 1953	1°59′ N.	156°09′ W.	Im	110	Dec. 9, 1953	2°01′ N.	158°15′ W.	Im	9
Dec. 8, 1953	2°14′ N.	157°08′ W.	Im	110	Dec. 8, 1953	2°14′ N.	157°08′ W.	Im	

On several cruises, observations were made on the state of maturity of ovaries which, with a few exceptions, were then discarded. Although these field observations were subjective and liable to differences between observers, they were used to supplement the seasonal and areal coverage. After discussion with the various observers, and after comparisons of field observations with laboratory classifications, we were able to classify most of the ovaries reliably into two groups, "inactive" (immature and intermediate) and "active" (maturing and ripe). Field classifications are given in table 2. Questionable observations were not considered, and are not included in the table.

TABLE 2.—*Data on yellowfin tuna specimens from the central equatorial Pacific for which maturity determinations were made in the field*

[A, active; I, inactive]

Date	Position		Stage of maturity	Fish length	Date	Position		Stage of maturity	Fish length
	Latitude	Longitude				Latitude	Longitude		
				Cm.					*Cm.*
May 28, 1954	4°02′ N.	159°34′ W.	A	149	June 11, 1954	0°26′ S.	158°57′ W.	A	14
May 30, 1954	3°58′ N.	159°04′ W.	A	140	June 14, 1954	0°13′ S.	160°02′ W.	A	14
May 28, 1954	4°02′ N.	159°34′ W.	A	139	June 15, 1954	0°30′ S.	160°19′ W.	A	14
Do	4°02′ N.	159°34′ W.	A	123	June 3, 1954	1°43′ N.	158°28′ W.	A	14
May 17, 1954	5°58′ N.	162°52′ W.	A	120	June 7, 1954	1°52′ N.	156°47′ W.	A	14
May 27, 1954	4°17′ N.	160°28′ W.	A	118	June 15, 1954	0°30′ S.	160°19′ W.	A	14
May 28, 1954	4°02′ N.	159°34′ W.	A	114	Do	0°30′ S.	160°19′ W.	A	14
Do	4°02′ N.	159°34′ W.	I	118	June 11, 1954	0°26′ S.	158°57′ W.	A	14
Do	4°02′ N.	159°34′ W.	I	116	June 14, 1954	0°13′ S.	160°02′ W.	A	14
Do	4°02′ N.	159°34′ W.	I	114	June 10, 1954	0°50′ N.	158°53′ W.	A	14
Do	4°02′ N.	159°34′ W.	I	109	June 15, 1954	0°30′ S.	160°19′ W.	A	14
May 30, 1954	3°58′ N.	159°04′ W.	I	108	Do	0°30′ S.	160°19′ W.	A	14
May 25, 1954	4°45′ N.	160°11′ W.	I	106	June 13, 1954	0°18′ S.	160°16′ W.	A	13
May 28, 1954	4°02′ N.	159°34′ W.	I	106	June 14, 1954	0°13′ S.	160°02′ W.	A	13
Do	4°02′ N.	159°34′ W.	I	103	June 12, 1954	0°14′ S.	160°00′ W.	A	13
Do	4°02′ N.	159°34′ W.	I	102	June 13, 1954	0°18′ S.	160°16′ W.	A	13
May 27, 1954	4°17′ N.	160°28′ W.	I	101	June 14, 1954	0°13′ S.	160°02′ W.	A	13
May 30, 1954	3°58′ N.	159°04′ W.	I	100	June 12, 1954	0°14′ S.	160°00′ W.	A	13
May 25, 1954	4°45′ N.	160°11′ W.	I	98	June 13, 1954	0°18′ S.	160°16′ W.	A	13
May 30, 1954	3°58′ N.	159°04′ W.	I	97	June 10, 1954	0°50′ N.	158°53′ W.	A	12
Do	3°58′ N.	159°04′ W.	I	96	June 14, 1954	0°13′ S.	160°02′ W.	A	12
Do	3°58′ N.	159°04′ W.	I	93	June 12, 1954	0°14′ S.	160°00′ W.	A	12
Do	3°58′ N.	159°04′ W.	I	93	Do	0°14′ S.	160°00′ W.	A	12
Do	3°58′ N.	159°04′ W.	I	93	Do	0°14′ S.	160°00′ W.	A	12
Do	3°58′ N.	159°04′ W.	I	92	Do	0°14′ S.	160°00′ W.	A	12
Do	3°58′ N.	159°04′ W.	I	92	Do	0°14′ S.	160°00′ W.	A	12
Do	3°58′ N.	159°04′ W.	I	91	Do	0°14′ S.	160°00′ W.	A	12
Do	3°58′ N.	159°04′ W.	I	91	June 8, 1954	2°01′ N.	157°09′ W.	A	11
Do	3°58′ N.	159°04′ W.	I	91	June 15, 1954	0°30′ S.	160°19′ W.	A	9
Do	3°58′ N.	159°04′ W.	I	89	June 8, 1954	2°01′ N.	157°09′ W.	I	12
May 25, 1954	4°45′ N.	160°11′ W.	I	88	June 12, 1954	0°14′ S.	160°00′ W.	I	12
May 30, 1954	3°58′ N.	159°04′ W.	I	88	Do	0°14′ S.	160°00′ W.	I	12
Do	3°58′ N.	159°04′ W.	I	88	Do	0°14′ S.	160°00′ W.	I	11
Do	3°58′ N.	159°04′ W.	I	87	June 13, 1954	0°18′ S.	160°16′ W.	I	11
Do	3°58′ N.	159°04′ W.	I	86	June 8, 1954	2°01′ N.	157°09′ W.	I	11
May 25, 1954	4°45′ N.	160°11′ W.	I	84	June 12, 1954	0°14′ S.	160°00′ W.	I	11
May 30, 1954	3°58′ N.	159°04′ W.	I	83	June 4, 1954	2°03′ N.	157°40′ W.	I	11
June 15, 1954	0°30′ S.	160°19′ W.	A	151	June 13, 1954	0°18′ S.	160°16′ W.	I	10
June 14, 1954	0°13′ S.	160°02′ W.	A	150	June 4, 1954	2°03′ N.	157°40′ W.	I	10
June 15, 1954	0°30′ S.	160°19′ W.	A	150	Do	2°03′ N.	157°40′ W.	I	10
June 12, 1954	0°14′ S.	160°00′ W.	A	147	June 8, 1954	2°01′ N.	157°09′ W.	I	9

TABLE 2.—*Data on yellowfin tuna specimens from the central equatorial Pacific for which maturity determinations were made in the field*—Continued

Date	Position		Stage of maturity	Fish length	Date	Position		Stage of maturity	Fish length
	Latitude	Longitude				Latitude	Longitude		
				Cm.					*Cm.*
Aug. 25, 1952	3°26′ N.	140°08′ W.	A	142	Aug. 24, 1953	4°43′ N.	160°00′ W.	I	99
Aug. 27, 1952	1°33′ N.	140°13′ W.	I	154	Do	4°43′ N.	160°00′ W.	I	96
Do	1°33′ N.	140°13′ W.	I	152	Do	4°43′ N.	160°00′ W.	I	96
Do	1°33′ N.	140°13′ W.	I	150	Do	4°43′ N.	160°00′ W.	I	95
Do	1°33′ N.	140°13′ W.	I	150	Do	4°43′ N.	160°00′ W.	I	93
Do	1°33′ N.	140°13′ W.	I	149	Do	4°43′ N.	160°00′ W.	I	88
Aug. 25, 1952	3°26′ N.	140°08′ W.	I	148	Sept. 7, 1952	1°42′ N.	141°24′ W.	I	156
Aug. 26, 1952	2°23′ N.	140°12′ W.	I	148	Sept. 3, 1952	4°04′ N.	140°09′ W.	I	150
Do	2°23′ N.	140°12′ W.	I	148	Sept. 7, 1952	1°42′ N.	141°24′ W.	I	149
Aug. 27, 1952	1°33′ N.	140°13′ W.	I	148	Sept. 9, 1952	2°33′ N.	143°22′ W.	I	148
Aug. 28, 1952	1°00′ N.	140°22′ W.	I	148	Sept. 2, 1952	3°05′ N.	140°02′ W.	I	147
Aug. 25, 1952	3°26′ N.	140°08′ W.	I	147	Do	3°05′ N.	140°02′ W.	I	145
Aug. 27, 1952	1°33′ N.	140°13′ W.	I	147	Sept. 5, 1952	2°25′ N.	140°32′ W.	I	145
Do	1°33′ N.	140°13′ W.	I	144	Sept. 2, 1952	3°05′ N.	140°02′ W.	I	144
Aug. 28, 1952	1°00′ N.	140°22′ W.	I	144	Sept. 7, 1952	1°42′ N.	141°24′ W.	I	143
Aug. 26, 1952	2°23′ N.	140°12′ W.	I	142	Sept. 9, 1952	2°33′ N.	143°22′ W.	I	143
Aug. 27, 1952	1°33′ N.	140°13′ W.	I	142	Sept. 1, 1952	3°31′ N.	140°28′ W.	I	142
Do	1°33′ N.	140°13′ W.	I	141	Sept. 7, 1952	1°42′ N.	141°24′ W.	I	139
Do	1°33′ N.	140°13′ W.	I	141	Sept. 5, 1952	2°25′ N.	140°32′ W.	I	136
Do	1°33′ N.	140°13′ W.	I	138	Sept. 11, 1952	2°57′ N.	147°22′ W.	A	157
Aug. 26, 1952	2°23′ N.	140°12′ W.	I	132	Sept. 18, 1952	3°30′ N.	151°54′ W.	A	150
Aug. 24, 1952	4°28′ N.	139°51′ W.	I	131	Sept. 16, 1952	2°28′ N.	150°38′ W.	A	146
Aug. 28, 1952	1°00′ N.	140°22′ W.	I	121	Sept. 18, 1952	3°39′ N.	151°54′ W.	A	144
Aug. 24, 1952	4°28′ N.	139°51′ W.	I	112	Sept. 19, 1952	3°49′ N.	152°10′ W.	A	143
Aug. 27, 1953	9°00′ N.	159°40′ W.	A	147	Sept. 15, 1952	2°05′ N.	150°23′ W.	A	142
Aug. 25, 1953	6°10′ N.	160°02′ W.	A	141	Sept. 19, 1952	3°49′ N.	152°10′ W.	A	142
Aug. 26, 1953	7°50′ N.	159°24′ W.	A	140	Sept. 18, 1952	3°39′ N.	151°54′ W.	A	138
Do	7°50′ N.	159°24′ W.	A	140	Sept. 16, 1952	2°28′ N.	150°38′ W.	A	137
Aug. 21, 1953	1°11′ N.	160°08′ W.	A	134	Sept. 17, 1952	3°26′ N.	151°40′ W.	A	137
Aug. 22, 1953	2°08′ N.	160°24′ W.	A	128	Sept. 16, 1952	2°28′ N.	150°38′ W.	A	135
Aug. 27, 1953	9°00′ N.	159°40′ W.	A	128	Sept. 11, 1952	2°57′ N.	147°22′ W.	I	148
Aug. 22, 1953	2°08′ N.	160°24′ W.	A	123	Sept. 14, 1952	1°48′ N.	150°05′ W.	I	144
Do	2°08′ N.	160°24′ W.	A	107	Sept. 10, 1952	2°08′ N.	145°21′ W.	I	143
Aug. 24, 1953	4°43′ N.	160°00′ W.	I	140	Sept. 11, 1952	2°57′ N.	147°22′ W.	I	143
Aug. 22, 1953	2°08′ N.	160°24′ W.	I	125	Sept. 15, 1952	2°05′ N.	150°23′ W.	I	142
Aug. 24, 1953	4°43′ N.	160°00′ W.	I	112	Sept. 14, 1952	1°48′ N.	150°05′ W.	I	135
Do	4°43′ N.	160°00′ W.	I	111	Sept. 10, 1952	2°08′ N.	145°21′ W.	I	134
Aug. 23, 1953	3°22′ N.	160°24′ W.	I	108	Sept. 15, 1952	2°05′ N.	150°23′ W.	I	134
Do	3°22′ N.	160°24′ W.	I	104	Sept. 13, 1952	1°22′ N.	149°54′ W.	I	133
Do	3°22′ N.	160°24′ W.	I	100	Sept. 16, 1952	2°28′ N.	150°38′ W.	I	117

Additional data (table 3) are available from field observations reported by the Iwate Prefecture Fishery Experiment Station (1953a and 1953b), which were obtained from Japanese longline expeditions into this area. As with the POFI field observations, the stages of maturity were combined into two groups, "active" and "inactive", and the "spent" category was disregarded. Other pertinent information found in these reports is as follows: The fishing area for the April cruise was between latitudes 9° N. and 11° N. and longitudes 170° W. and 173° W. Fish caught on this cruise ranged from 110 to 150 cm. in length, with only one fish measuring less than 120 cm. Fishing during June and July was done at 3° N. to 4° N. and 175° W. to 177° W. Fork lengths ranged from 114 to 173 cm., with only two fish measuring less than 120 cm. Eighty percent of the fish were caught in June, and the rest were caught in July.

TABLE 3.—*Number of yellowfin tuna in various stages of maturity, according to Iwate Prefecture Fishery Experiment Station*

Date	Immature	Maturing	Mature	Ripe	Spent	Location	
						Longitude	Latitude
Apr. 4–24, 1953	3	4	10	14	4	9° N.–11° N.	170° W.–173° W.
June 22–July 3, 1953	29	41	97	26	22	3° N.–4° N.	175° W.–177° W.

Note.—For further data see station reports (1953a and 1953b).

SIZE OF FISH AT FIRST SPAWNING

To determine the size of first-spawning fish, the fork lengths collected by POFI were grouped into classes of 10 cm., and the percentage of fish in the "active" category (maturing and ripe stages), as determined by ovary examination, was calculated for each length class. The results, illustrated in figure 1, show that all the fish smaller than 70 cm. were in a nonspawning condition. In the 70-to-79-cm. class (about 15 to 22 lbs.), 6.9

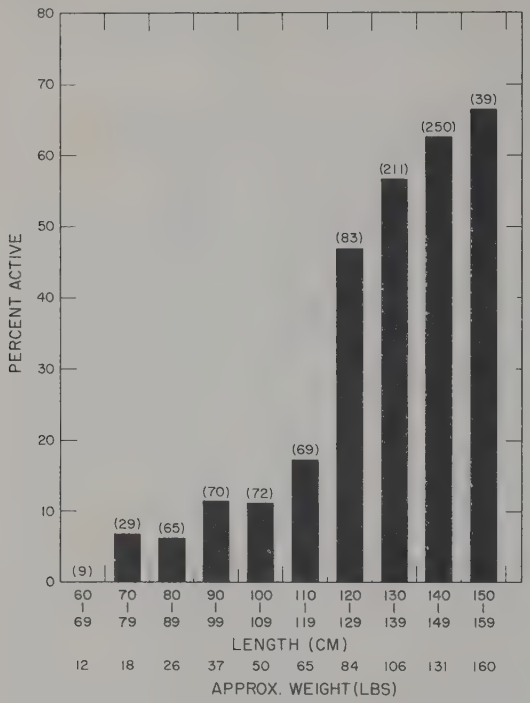


FIGURE 1.—Percentages of sexually active fish at different fork lengths. Figures in parentheses indicate the numbers of individuals on which the percentages are based.

percent were in the maturing or ripe stages. The percentage of sexually active fish increased gradually and irregularly from this length class through the 110-to-119-cm. class (about 57 to 72 lbs.), of which 17.4 percent were active. In the next 10-cm. class (about 74 to 92 lbs.), the percentage of reproductively active fish jumped sharply to 47.0 percent. Above this class the percentage of active fish increased steadily with length. Of the fish measuring 150 to 159 cm. (about 145 to 172 lbs.), 66.7 percent were active.

These data suggest that, although yellowfin as small as 70 cm. are capable of reproducing, the greater part of the population reaches sexual maturity at about 120 cm. Schaefer and Marr (1948), however, noted that in Costa Rican waters yellowfin ranging from 70 to 100 cm. spawn later in the year than the larger fish. This presents the possibility that larger fish have longer spawning periods than smaller fish, which in turn suggests that the smaller percentage of sexually active fish from 70 to 120 cm. in our samples may have resulted from a shorter spawning season rather than from a difference between the proportions of sexually mature fish above 120 cm. and those below 120 cm. Although the representation of fish from 70 to 120 cm. for each month is spotty in our samples, an examination of the monthly percent maturing and ripe (table 4) shows the peak percentage to be far less than that reached by the larger fish. This supports our interpretation of the results, that is, that the greater part of the population reaches sexual maturity at about 120 cm.

TABLE 4.—*Monthly percentages of sexually active yellowfin tuna below 120 cm. fork length*

Month	Fraction active	Percent active
January	1/12	8.3
February	2/26	7.6
March	0/1	0.0
April	2/18	11.0
May	11/101	10.0
June	11/45	24.4
July	0/1	0.0
August	3/24	12.5
September	4/12	33.3
October	0/4	0.0
November	0/31	0.0
December	0/33	0.0

LOCALITY OF SPAWNING

The data were grouped by months and by 10-degree longitudinal sections. The data for those ovaries collected between 115°00′ W. and 124°59′ W. are shown in table 5 in the 120° W. longitudinal section (the midpoint of that section), those collected between 125°00′ and 134°59′ W. in the 130° W. section, and so on, with the exception of the 180° section, which includes 175°00′ W. to 180°. Because the percentage of sexually active fish below 120 cm. was so much smaller, only fish above this size were considered in order to get results that could be used for comparison. The percentage of active fish for each month for each 10-degree section was calculated. The percentages for June and July along 180° were calculated from summarized Japanese data, which did not separate the catch of those 2 months. To arrive at the monthly totals for these months (in the extreme right-hand column of table 5), the 193 fish caught along 180° were separated into 154 fish for June and 39 fish for July, because 80 percent of the catch was made in June.

The results (table 5) show that all the sections had at least one month in which 85 percent or more of the fish were sexually active. This, coupled

TABLE 5.—*Fractions of samples of sexually active yellowfin tuna (maturing and ripe) at various longitudes, by months*

[Percentage of sexually mature fish in sample in parentheses]

Month	At longitude—							Total
	180°	170° W.	160° W.	150° W.	140° W.	130° W.	120° W.	
January			1/6 (16.7%)					1/6 (16.7%)
February	9/11 (81.8%)	1/2 (50.0%)	13/32 (40.6%)	14/30 (46.7%)				37/75 (49.3%)
March		14/16 (87.5%)		1/1 (100.0%)	34/35 (97.1%)			49/52 (94.2%)
April		28/31 (90.3%)						28/31 (90.3%)
May		7/8 (87.5%)	23/27 (85.2%)				4/4 (100.0%)	34/39 (87.2%)
June	131/154 (85.0%)	7/9 (77.8%)	38/43 (88.4%)			9/10 (90.0%)	1/1 (100.0%)	186/217 (85.7%)
July	33/39 (85.0%)	2/3 (66.7%)						35/42 (83.3%)
August			37/53 (69.8%)	7/7 (100.0%)	11/39 (28.2%)			55/99 (55.6%)
September			5/18 (27.8%)	83/115 (72.2%)	22/30 (73.3%)			110/163 (67.5%)
October			1/1 (100.0%)	3/8 (37.5%)			1/3 (33.3%)	5/12 (41.7%)
November		4/6 (66.7%)	5/28 (17.9%)	0/3 (0.0%)		1/2 (50.0%)	1/5 (20.0%)	11/44 (25.0%)
December			0/31 (0.0%)	0/1 (0.0%)				0/32 (0.0%)

with the fact that larvae below 10 mm. have been found in all of these sections (Matsumoto[1]) indicates that yellowfin spawning occurs throughout the central equatorial Pacific. The fact that spawning probably occurs throughout the entire equatorial Pacific is indicated by additional records of spawning yellowfin in the western area by Wade (1950 and 1951), Marr (1948), and Shimada (1951), and in the eastern area by Schaefer and Marr (1948) and Mead (1951).

TIME OF SPAWNING

The percentage of sexually active fish of 120 cm. and longer was calculated for each month of the year and was plotted on a graph (fig. 2). Yellowfin that had almost reached the spawning state were found in each month except December, and the greatest percentages of active fish occurred from March (94.2%) through July (83.3%). It was only during November, December, and January that the occurrence of maturing and ripe fish dropped below 40 percent. This, however, does not prove that spawning is a year-round activity, inasmuch as the length of time that the fish are in these stages before spawning is not known.

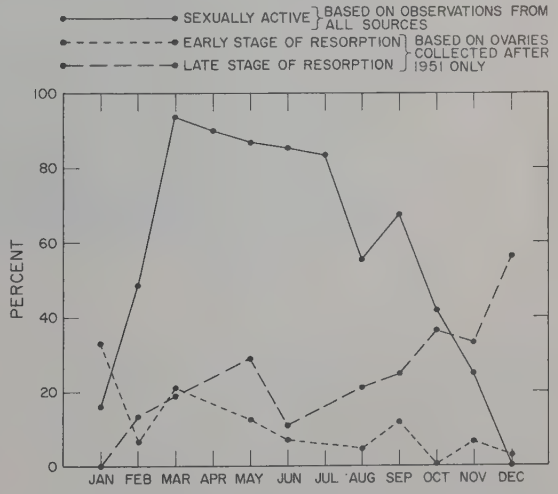


FIGURE 2.— Monthly percentages of yellowfin tuna sexually active or with residual eggs.

To define the spawning season further, the occurrence of residual eggs in these larger fish was investigated with respect to time. The results, plotted in figure 2, show that ovaries with early-

[1] Matsumoto, Walter M.: Descriptions of four species of tuna larvae and their distribution in central Pacific waters. POFI. (Unpublished MS.)

stage residual eggs have the same occurrence pattern as maturing and ripe ovaries. This is true for all the months except January, which is represented by an inadequate sample. The occurrence of these early-stage residual eggs indicates that spawning actually is a year-round occurrence.

Spawning in other equatorial areas of the Pacific likewise seems to be protracted. Schaefer and Marr (1948) found indications of a prolonged spawning season off Costa Rica. Wade (1950) found that the spawning period of yellowfin in the Philippine Islands extended over a considerable period, but that it was most intense during May, June, July, and August. It is probable that the prolonged spawning season is accompanied by multiple spawning—in other words, there is more than one spawning per fish in a spawning season. June (1953) considered this to be true for yellowfin in Hawaiian waters, after studying the progression of modal groups in egg-diameter frequencies.

DESCRIPTION OF STAGES IN RESORPTION OF RESIDUAL EGGS

In the beginning of this study, several structures found in the ovaries could not be readily identified. As more ovaries were examined, it became evident that these structures were the remains of ripe eggs from a previous spawning which were in different stages of resorption. The following descriptions of these stages are based on gross microscopic examination and are intended to aid future workers in recognizing these structures.

Immediately after spawning, these residual eggs (fig. 3) generally resemble the ripe eggs, except that they become shrivelled owing to shrinking of the yolk mass and the resulting collapse of the chorion. The oil sac is usually ruptured, and the released oil appears as bright yellow droplets. The eggs at this stage are still loose and translucent.

Subsequently the eggs lose their translucence and collect in masses of semiopaque tubules. The eggs are not within the tubule but are entangled in the many disordered convolutions of the tubule.

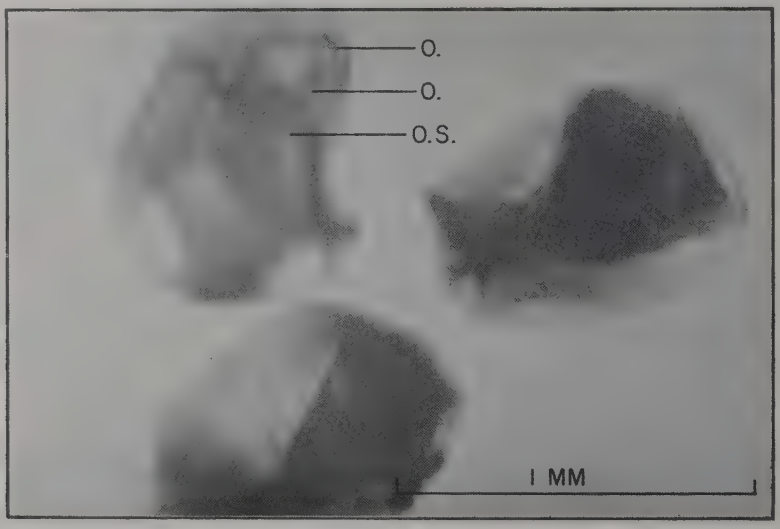


FIGURE 3.—Individual residual eggs; O., oil droplet; O. S., oil sac.

FIGURE 4.—Piece of tubule teased from ovary with residual eggs; i. t., inner tubule; o. t., outer tubule.

The tubular diameter is about 0.20 mm. Within this tubule lies another tubule with a diameter of 0.05 mm. Circular transverse ridges on the wall of the outer tubule give it a striated appearance. Figure 4 shows a short section of a tubule that had been teased from a mass.

Histologically, these masses of tubules and eggs are found to be surrounded by a connective tissue stroma (fig. 5). The wall of the outer tubule seems to be composed of reticular connective tissue. The wall of the inner tubule is made up of a single layer of closely arranged minute cells (3 μ diameter) with relatively large, deep-staining nuclei.

The origin and function of these tubules are open to question, but their proximity to the residual eggs suggests that they are involved in the absorption of these eggs.

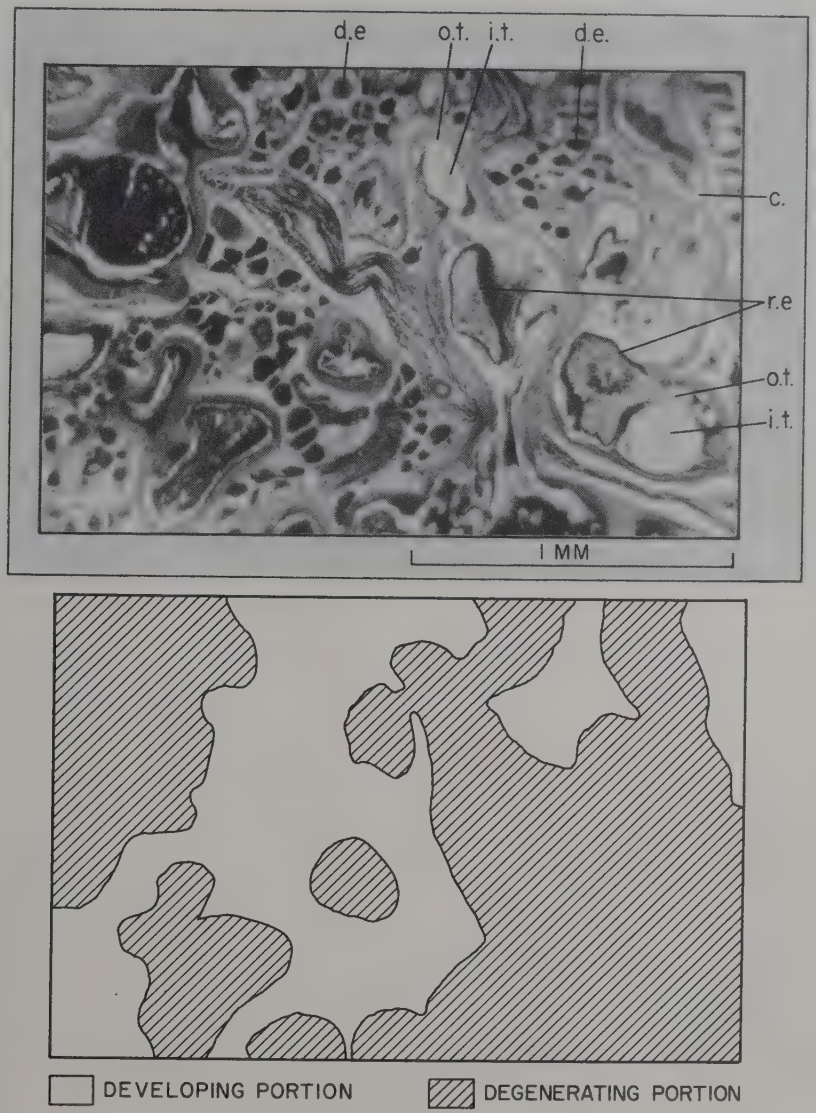


FIGURE 5.—Above: Part of section through ovary showing residual egg mass *in situ*; c., connective tissue capsule; d. e., developing egg; i. t., inner tubule; o. t., outer tubule; r. e., residual egg. Below: Diagram of this section, outlining developing and degenerating portions.

The masses of eggs, tubules, and connective tissue which are scattered throughout the ovary appear to shrink with the passage of time. An examination of later stages shows that the residual eggs are not arranged entirely haphazardly but are lined up to form indistinct cords (fig. 6). These masses eventually shrink to nondescript particles (fig. 7) before they are finally lost in the ovary.

OCCURRENCE OF NEMATODES IN THE OVARIES

While examining the eggs, we observed severa ovaries with nematodes, ranging from 0.5 cm. to 4 cm. in length. The specimens were in too poor a state of preservation to identify.

Of 25 ovaries examined for nematodes, 22 (88%) were infested. The extent of infestation did not appear to be serious enough to affect the

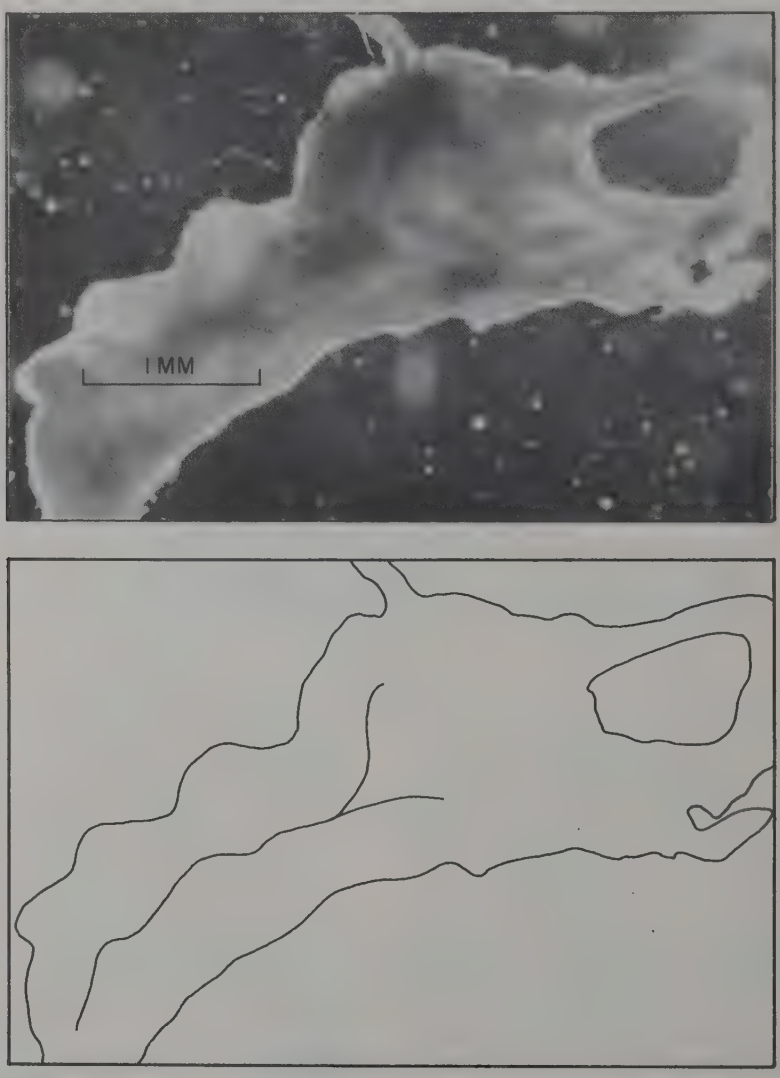


FIGURE 6.—Above: Residual egg mass teased from ovary. Below: Diagram of this mass, outlining the rows of eggs

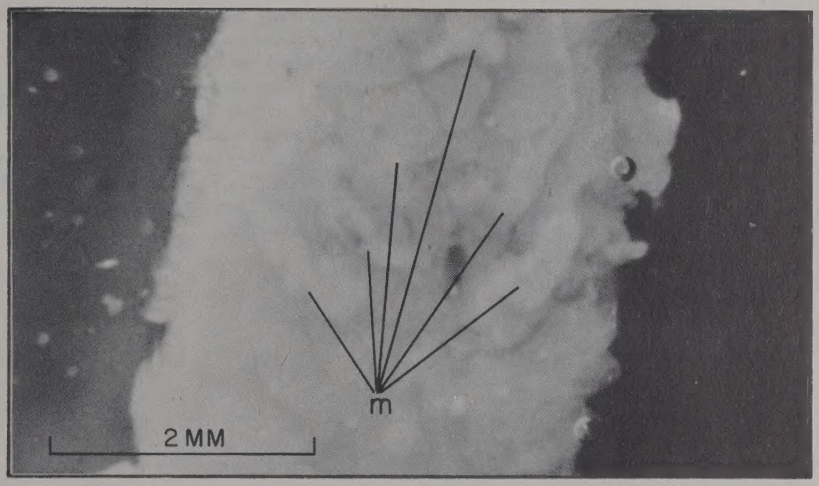


FIGURE 7.—Part of ovary showing shrunken masses of residual eggs; m., mass of residual eggs.

functioning of the ovaries. There were seldom more than five worms in a single ovary, and in only one instance did the ovarian tissue seem to be pathological owing to heavy infestation. Fish with infested ovaries were found throughout the central equatorial Pacific.

SUMMARY

This study is based on data obtained in the field relative to the time and place of spawning and the size of yellowfin tuna at time of spawning, and on laboratory examination of ovaries of yellowfin tuna obtained on POFI exploratory-fishing trips made in the central equatorial Pacific from February 1950 to June 1954. Study of the ovaries and of the data on the size and distribution of the spawning fish led to the following conclusions: (1) The size at sexual maturity may be as small as 70 cm., but usually is greater than 120 cm.; (2) the spawning season extends throughout most of the year, with November, December, and January the months of lowest spawning intensity; (3) the spawning grounds seem to include the entire equatorial Pacific.

During the course of this investigation, stages in the resorption of residual eggs were observed and described.

Unidentified nematodes were found in 88 percent of a sample of 25 ovaries. In most instances, the nematodes did not seem to be present in sufficient numbers to affect egg production seriously.

LITERATURE CITED

BINI, GIORGIO.
1952. Osservazioni sulla fauna marina delle coste del Chile e del Perù con speciale riguardo alle specie ittiche in generale ed ai tonni in particolare. Bollettino di Pesca, Piscicoltura e Idriobiologia, vol. 7 (n. s.), fasc. 1: 11–60. Roma.

IWATE PREFECTURE FISHERY EXPERIMENT STATION.
1953a. South Sea tuna fishing survey. Rept. No. 1.
1953b. South Sea tuna fishing survey. Rept. No. 2.

JUNE, FRED C.
1953. Spawning of yellowfin tuna in Hawaiian waters. U. S. Department of the Interior, Fish and Wildlife Service, Fishery Bull., No. 77, vol. 54, pp. 47–64.

MARR, JOHN C.
1948. Observations on the spawning of oceanic skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Neothunnus macropterus*) in the northern Marshall Islands. U. S. Department of the Interior, Fish and Wildlife Service, Fishery Bull., No. 44, vol. 51, pp. 201–206.

MEAD, GILES W.
1951. Postlarval *Neothunnus macropterus*, *Auxis thazard*, and *Euthynnus lineatus* from the Pacific Coast of Central America. U. S. Department of the Interior, Fish and Wildlife Service, Fishery Bull., No. 63, vol. 52, pp. 121–127.

SCHAEFER, MILNER B., and J. C. MARR.
1948. Spawning of yellowfin tuna (*Neothunnus macropterus*) and skipjack (*Katsuwonus pelamis*) in the Pacific Ocean off Central America, with descriptions of juveniles. U. S. Department of the Interior, Fish and Wildlife Service, Fishery Bull., No. 44, vol. 51, pp. 187–196.

SHIMADA, BELL M.
1951. Contributions to the biology of tunas from the western equatorial Pacific. U. S. Department of the Interior, Fish and Wildlife Service, Fishery Bull., No. 62, vol. 52, pp. 111–119.

WADE, CHARLES B.
1950. Observations on the spawning of Philippine tuna. U. S. Department of the Interior, Fish and Wildlife Service, Fishery Bull., No. 55, vol. 51, pp. 409–423.
1951. Larvae of tuna and tuna-like fishes from Philippine waters. U. S. Department of the Interior, Fish and Wildlife Service, Fishery Bull., No. 57, vol. 51, pp. 445–485.

U. S. GOVERNMENT PRINTING OFFICE : 1957 O - 406090